IV. International Congress of the Turkish
Journal of Agriculture - Food Science and Technology

TURJAF 2025

On behalf of Prof. Dr. MUSA SARICA

28-30 April 2025

10.00

NÖHÜ Şehit Ömer Halisdemir
Congress and Cultural Center



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IV. INTERNATIONAL CONGRESS OF THE TURKISH JOURNAL OF AGRICULTURE - FOOD SCIENCE AND TECHNOLOGY (TURJAF_2025)
APRİL 28-30, 2025, NIGDE/TURKIYE

Oturum Session	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
AÇILIŞ	09:00-10:00	Kayıt/Registration		
	10:00-11:20	Açılış Konuşmaları / Opening Seramony	Onuruna TURJAF 2025 Kongresi düzenlenen Prof.Dr. Musa SARICA'nın özgeçmişinin okunması	
		Prof.Dr. Ahmet ŞEKEROĞLU	TBTF Dekanı/Dean of FAST	Türkiye
		Prof.Dr. Hasan ELEROĞLU	Editor of TURSTEP	Türkiye
		Prof.Dr. Musa SARICA	Editor of TURJAF	Türkiye
		Dr Şerafettin Çakal	TAGEM Genel. Müdür Yrd. / Deputy Director General of TAGEM)	Türkiye
		Prof.Dr. Hasan USLU	NOHU Rektörü/Rector of NOHU	Türkiye
		Dr. Cahit ÇELİK	Niğde Valisi/Governor of Niğde (Teşrifleri durumunda)	Türkiye
	Kongre Açılış Sunumu/ Opening Presentation of the Congress	Prof.Dr. Musa SARICA	Türkiye'de etlik piliç ıslahı alanında yapılan son çalışmalar ve gelecek beklentileri / Recent studies and future expectations in broiler breeding in Turkey	Türkiye
	11:20-11:40	Mola /Break		

28 Nisan 2025 Pazartesi / 28 April 2025 Monday
Salon 1923 – Hall 1923
AÇILIŞ / OPENING

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
1. Oturum		09:00-10:00	Kayıt/Registration		
		10:00-11:20	Açılış Konuşmaları / Opening Seramony	Onuruna TURJAF 2025 Kongresi düzenlenen Prof.Dr. Musa SARICA'nın özgeçmişinin okunması	
			Prof.Dr. Ahmet ŞEKEROĞLU	TBTF Dekanı/Dean of FAST	Türkiye
			Prof.Dr. Hasan ELEROĞLU	Editor of TURSTEP	Türkiye
			Prof.Dr. Musa SARICA	Editor of TURJAF	Türkiye
			Dr Şerafettin Çakal	TAGEM Genel. Müdür Yrd. / Deputy Director General of TAGEM)	Türkiye
			Prof.Dr. Hasan USLU	NOHU Rektörü/Rector of NOHU	Türkiye
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	1	Kongre Açılış Sunumu/ Opening Presentation of the Congress	Prof.Dr. Musa SARICA	Türkiye'de etlik piliç ıslahı alanında yapılan son çalışmalar ve gelecek beklentileri / Recent studies and future expectations in broiler breeding in Turkey	Türkiye
		11:20-11:40	Mola /Break		

28 Nisan 2025 Pazartesi / 28 April 2025 Monday

Salon 1923 – Hall 1923

Oral Presentation – Yüz Yüze - Face to Face

Oturum Başkanı / Moderator: Prof.Dr. Mustafa AVCI

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
1. Oturum	2	11:40	Prof. Dr. Esvet AÇIKGÖZ	İklim Değişikliği ve Yem Bitkileri Islahına Etkileri / Climate Change and Its Effects on Forage Crops Breeding	Türkiye
	3	12:00	Dr. Hümeyra YAMAN	Plant Breeding in the Axis of Climate Change / İklim Değişikliği Ekseninde Bitki Islahı	Türkiye

Mola / Break

12:30 – 13:30

28 Nisan 2025 Pazartesi / 28 April 2025 Monday

Salon 1923 – Hall 1923

Oral Presentation – Yüz Yüze - Face to Face

Oturum Başkanı / Moderator: Prof.Dr. Ayhan GÖKÇE

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
2. Oturum	4	13:30	Doç. Dr. Ahmet UÇAR	Developments in Layer Breeding / Yumurta Tavuğu Islahındaki Gelişmeler	Türkiye
	5	13:50	Dr. Şerif ÖZONGUN	Fruit Research Institute	Türkiye
	6	14:10	Director ÜnaL AKAY	Turkish viticulture and its status in the World / Türkiye Bağcılığı Ve Dünyadaki Yeri	Türkiye
	7	14:30	Dr. Uğur PIRLAK	Potato Production in Türkiye and the World / Türkiye ve Dünyada Patates Üretimi	Türkiye
	8	14:50	Director Can UYAR	Green Deal and New Agricultural Order\Yeşil Mutabakat ve Yeni Tarım Düzeni	Türkiye
	9	15:10	Prof.Dr. Ayhan GÖKÇE	İklim Değişikliğinin İstilacı Tarımsal Zararlı Türlerin Yayılma Dinamiklerine Etkisi	Türkiye
Mola / Break 15:30 – 15:50					

28 Nisan 2025 Pazartesi / 28 April 2025 Monday

Salon 1923 – Hall 1923

Oral Presentation – Yüz Yüze - Face to Face

Oturum Başkanı / Moderator: Prof.Dr. Halil TOKTAY

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
3. Oturum	10	15:50	Hatice Dilaver, Kamil Fatih Dilaver	The Role of Artificial Intelligence in Increasing Milk Production on Dairy Farms: Yapay Zekanın Süt Çiftliklerinde Süt Üretimini Artırmadaki Rolü	Türkiye
	11	16:10	Hatice Dilaver, Kamil Fatih Dilaver	The Ecological Life of Eco-Villages	Türkiye
	12	16:30	Gülten Kaçar Avcı,*, Halil Toktay, Ramazan Canhilal	Niğde ili Patates Altın Kist Nematodu (Globodera rostochiensis) Popülasyonlarının Moleküler Tür Teşhisi	Türkiye
	13	16:50	Z. Erol1, H. Horasan, Jerina Rugji	Exploring the Impact of the Matrix on the Growth of Listeria monocytogenes	Türkiye
	14	17:10	Abdul Wakil Ayan, Sümeyra Gürkök	Biosurfactant Production by Aeromonas caviae	Türkiye
	15	17:30			

28 Nisan 2025 Pazartesi / 28 April 2025 Monday
Salon 1071 – Hall 1071
Oral Presentation - Yüz Yüze - Face to Face
Oturum Başkanı / Moderator: Prof. Dr. Esvet AÇIKGÖZ

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
1. Oturum	1	13:30	Uğur Pırlak, Necmettin Oğuz Demir	Dünya'da ve Türkiye'de Patates Üretimi İle Yerli ve Milli Patates Geliştirme Çalışmaları	
	2	13:50	Özlem Erol	Alternative Protein Sources Used in Poultry Nutrition: Insects	Türkiye
	3	14:10	Serap Özer	Biostimulants Commonly Preferred in Potato Cultivation in Nevşehir Region and Their Effects on Production	Türkiye
	4	14:30	Muhammad Salim, Shahid Sattar	Effect of synthetıc insectıcıdes and botanıcal extract agaınst whıtefly, Bemısıa tabacı (Gennadıus) (Hemıptera: Aleyrodıdae) in dıfferent okra varıetıes	Pakistan
	5	14:50	Muhammad Salim	Lethal and sublethal effects of neem leaves extract (*Azadirachta indica)* against pink hibiscus mealy bug (*Maconellicoccus hirsutus*) (Hemiptera: Psudococcidae)	Pakistan
	6	15:10	Ergün Ergenekon*, Murat Özdal, Ömer Köksal Erman	Isolation of Cellulolytic Bacterium from the Digestive Tract of the Leptinotarsa decemlineata (Colorado Potato Beetle)	Türkiye
Mola / Break 15:10 – 15:30					

28 Nisan 2025 Pazartesi / 28 April 2025 Monday
Salon 1071 – Hall 1071
Oral Presentation - Yüz Yüze - Face to Face
Oturum Başkanı / Moderator: Prof. Dr. Ayhan CEYHAN

Oturum Session	Sunum Presentation	Saati Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
2. Oturum	7	15:50	Tuğba Özkan	Kuraklık ve Sıcaklık Stresinin Patates Bitkisi Üzerine Etkileri	Türkiye
	8	16:10	Haydar Karadaş, Ali Eren, Altan Erkılınç, Mikail Eren Taşar, Melike Pelin Çekiç, Meliha İrem Aras, Ahmet Uçar	Effect of Genotype and Sex on Slaughter and Carcass Characteristics in Quail	Türkiye
	9	16:30	A. Çağlı, U. Pırlak, T. Özkan, Dr. N. O. Demir, G. Kaçar Avcı, E. İnan, M. Uzlaşır	Patates Mini Yumru Üretiminde Akan Su Kültürü, Aeroponik ve Topraklı Ortam Yöntemlerinin Verim ve Verim Unsurları Yönleriyle Karşılaştırılması	Türkiye
	10	16:50	Francisco Condori Tintaya, Tefide Kızıldeniz*, Oscar Fernandez Cutire, Junior Miranda Gutierrez, Yhudit Marili Mamani Llaca	Sustainable Irrigation Strategies for Enhancing Hass Avocado Yield in Arid Region of Tacna, Peru	Peru
	11	17:10	Mikail Yeniçeri, Ayşe Gül Filik, Hakan KIR, Gökhan Filik	Determination of the Effectiveness of Microbial Inoculants in Improving the Quality of Sorghum bicolor X Sorghum sudanese Silage	Türkiye
		17:30	Md. Habibur Rahman Mukul, Shamsunnaher, Md. Moniruzzaman, Afruz Zahan, Md. Niaz Morshed, Khandoker Khalid Ahmed, Md. Romel Bishwas, Mohammad Monsur, Md. Said Hossain, Most. Nilufar Yeasmin, Biswajit Karmakar Md Humayun Kabir, and Mir Mehedi Hasan*	AMMI and WAASB-Based Stability Model Analysis for Identifying High-Yielding Stable Blast Resistant Rice (Oryza sativa L.) Genotype	Bangladesh
		17:50	Mir Mehedi Hasana*, Zakaria Alamb, Md. Habibur Rahman Mukula, Afruz Zahana, Md. Niaz Morsheda, Khandoker Khalid Ahmeda, Md. Romel Bishwasa, Md. Abdul Gaffarc, Aparajita Badhand, Sanjida Aktere, Biswajit Karmakara, Md Humayun Kabira and Shamsunnahera	Selection of Stable and High-Yielding Short-Duration Inbred Rice (Oryza sativa L.) Genotypes for the Boro Season in Bangladesh Using WAASB and MTSI Indices	Bangladesh

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Salon 1299 – Hall 1299

Oral Presentation - Yüz Yüze - Face to Face

Oturum Başkanı / Moderator: Prof.Dr. Sedat KARAMAN

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
1. Oturum	1	11:30	Hatice Nur Kılıç Özel, Mustafa Boğa	Natural Bee Products for Calf Feeding	Türkiye
	2	11:50	Dilek İşler, Levent A. Ünlenen, Ufuk Demirel	Türkiye'deki Bazı Patates Çeşit Ve Hatlarının Moleküler Karakterizasyonu Ve Genetik Çeşitliliği	Türkiye
	3	12:10	Buket Cetiner	Sensory and Texture Profile Analyze of Bulgur Samples	Türkiye

Mola / Break

12:30 – 13:30

28 Nisan 2025 Pazartesi / 28 April 2025 Monday
Salon 1299 – Hall 1299
Oral Presentation - Yüz Yüze - Face to Face
Oturum Başkanı / Moderator: Prof.Dr. Sibel CANOĞULLARI DOĞAN

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
2. Oturum	4	13:30	Zeynep Ünal	Dijital Tarım	Türkiye
	5	13:50	Nisanur Alaca	Lamiaceae (ballıbabagiller)Türlerinin Peyzaj Tasarımında kullanım Olanakları	Türkiye
	6	14:10	Selin Kırım*, Muhammed Talha İnce	Sürdürülebilir Hayvansal Üretim İçin Su Mercimeği Potansiyeli	Türkiye
	7	14:30	Züleyha Aslan Ergenekon, Meryem Şengül Köseoğlu	Evaluation of Some Element Contents in Hypericum scabrum L. from Kükürtlü Village (Erzurum)	Türkiye
	8	14:50	Mohammad Abul Monsur, Mohammad Nazrul Islam, Mohammad Hasibur Rahman Hera, Quazi Shiren Akter Jahan	Rice, Zinc, disease severity, Di Impact of zinc fertilizer on zinc content rice varieties to curve the disease status at farmer's field in Bangladesh: Effect of micronutrient zinc fertilizer to increase disease resistance in farmers field	Bangladesh
	9	15:10	Anton J. Haverkort, Tefide Kizildeniz, Ayten Kubra Yagiz, Caner Yavuz, Ali Kaan Yetik, Ramazan İlhan Aytekin, Bayram Ali Yerlikaya	Exploring development, growth, yield and water use of several crops under climate change with LINTUL-MULTICROP, a statistical and mechanical simulation	Netherlands

Mola / Break
15:30 – 15:50

28 Nisan 2025 Pazartesi / 28 April 2025 Monday
Salon 1299 – Hall 1299
Oral Presentation - Yüz Yüze - Face to Face
Oturum Başkanı / Moderator: Doç.Dr. Hande BALTACIOĞLU

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
3. Oturum	10	15:50	Katibe Sinem Coruk, Betül Oskaybaş-Emlek, Cansel Murat, Arife Nur Kanber, Hande Baltacıoğlu	Multivariate Analysis Of The Effect Of Different Pre-Treatment Methods Before Drying On Some Quality Properties Of Potato	Türkiye
	11	16:10	Cevher Özden	The Impact of Climate Change on Agricultural Insurance: The Role of Artificial Intelligence	Türkiye
	12	16:30	Mutlu Bulut	The Place of Animal Production in the Agricultural Sector: Economic Contributions and Future Perspectives	Türkiye
	13	16:50	Burak Şen, Ayşe Topal, Ali Kaan Yetik	Methods Used in Calculating Water Footprint in Agricultural Production	Türkiye
	14	17:10	Özgür Kıvılcım Kılınç, François Laurent	Niğde Patates Ekim Alanlarında Bulunan Solanum spp. (Köpek Üzümü) Biyotiplerinin Metribuzin Kullanımına Bağlı Dayanıklılık Mekanizmaları	Türkiye
	15	17:30	Özgür Kıvılcım Kılınç	Nohut'ta (Cicer arietinum L.) metribuzinin metabolizasyonu ve transferi	Türkiye
		17:50	Barsham M. A.*, Nabiela M. Elbagir, Barri M. E. S	Serum Selenium Levels in Dromedary Camel (Camelus dromedarius) Orally Supplemented with Sodium Selenite and a Mixture of Sodium Selenite and Sodium Sulphate	Sudan

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Salon 1 – Hall 1
Oral Presentation – Online
Oturum Başkanı / Moderator: Furkan Baş

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
1. Oturum	1	09:00	Anita Bhandari, Tirth Narayan Yadav, Ajita Pokhrel, Abhisek Shrestha	Effect on Germination of Mung Beans (Vigna radiata W.) Using Different	Nepal
	2	09:15	Tirth Narayan Yadav, Vijay Singh, Anita Bhandari, Abhisek Shrestha	Effect of Seed Priming Using Botanical Extracts on Germination of Okra (Abelmoschus esculentus Var. Nancy)	Nepal
	3	09:30	Vijay Singh*, Tirth Narayan Yadav, Nitu Kumari Mahato1, Anita Bhandari, Abhisek Shrestha	Evaluation of Early Rice Genotypes for Yield and Yield Attributing Characters in Madhesh Province of Nepal	Nepal
	4	09:45	Zeshan Ali1*, Zinanone Rosaire Brottier	Impact of Storage Conditions on the Stability and Bioactivity of Date Vinegar: A Comprehensive Study on Its Efficacy in Managing Metabolic Diseases	China
	5	10:00	Saber Y. Adam, Madesh Muniyappan, Wael Ennab, Abdelkareem A. Ahmed,,, Hosameldeen Mohamed Husien, Mohamed Osman Abdalrahem Essa, Demin Cai*	The Role of Zinc Supplementation in Reducing Oxidative Stress via Histone Modifications in Heat-Stressed Broiler Chickens	China
	6	10:15	Dilip Kumar Jha	Integrated Agriculture-Aquaculture Systems for sustainable development in Rural Nepal	Nepal
	7	10:30	Bolat Seidanov, Zeliha Selamoglu, Mesut Selamoglu	The Role of Artificial Intelligent in Agricultural Applications: Trend Methods	Kazakhstan
Mola / Break 10:45 – 11:15					

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Salon 1 – Hall 1
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Oturum Başkanı / Moderator: Furkan Baş

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
2. Oturum	8	11:15	Bera R., Dey, P. , Bhattacharya, P. , Barik A.K., Saha, S. and Dutta Datta A.	Building Regenerative Agri-Net Zero Model: Bridging Corporate Responsibility and Farmers' Sustainability through Climate Action Strategies	India
	9	11:30	Das Biswas P., Dey, P. , Bhattacharya, P., Barik A.K., Saha, S. and Bera R.	Corporates' commitments from Net Zero to ESG Goal: Agri-Net Zero is the best pathway to attain Climate Action and Livelihood sustenance.	India
	10	11:45	K. Mukhopadhyay, R. Bera, P. Dey, M. Debnath, M. K. Samanta, S. C. Pramanik	Climate change impact and relevance of Regenerative Agriculture to sustained crop yield, reduced pesticide load, sustained farmers livelihood and carbon mitigation	India
	11	12:00	Bouledroua, D., Debbabi, H., Meghit Boumediene, K., Jribi, S., Ben Ismail, H., Doggui, D. & Sfayhi, D.	Bread Waste Patterns in Algeria: Insights into Sociodemographic Influences and Management Practices	Tunusia
	12	12:15	Borhen Dahmen	Valorization of Stale Bread in Tunisian Traditional Cookies: A Sustainable Approach to Maachech Formulation	Tunusia
	13				
	14				

Mola / Break
12:30 – 13:30

28 Nisan 2025 Pazartesi / 28 April 2025 Monday
Salon 1 – Hall 1
Oral Presentation – Online
Oturum Başkanı / Moderator: Ali Kaan Yetik

Microsoft Teams Link: TURJAF 2025 - Online - Salon 1 / Hall 1 | General | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
3. Oturum	15	13:30	Jerry Ampofo-Asiama, Claudia Asantewaa Gyimah, Vivianne Geraldo, Rosemond Godbless Dadzie, Emmanuel Azedaan Ayobe, Ernest Silvanus Dornor Asamani, Nazir Kizzie-Hayford	Assessment of Consumer Willingness to Consume Artificially-Sweetened Roselle Beverage	Gana
	16	13:45	Akwetey, WY., Rashid, B., Dekyi, F., Massawudu, A-A. and Gyamah, L.	Quality of smoked-cooked chicken sausage with soy flour and oil	Gana
	17	14:00	Rosemond Godbless Dadzie, Jerry Ampofo-Asiama, Nazir Kizzie-Hayford, Gifty Serwaa Otoo3, Isaaca Adade, Sandra Voryehor, Jesse Baidoo Emmanuel Azeedan Ayoobe	Gluten-free Noodles from Cassava-Bambara groundnut Composite Flour: Physicochemical Properties and Consumer Acceptability	Gana
	18	14:15	Haruna Abukari, Ziblim A. Imoro, Mathurin Zida, Amy Ickowitz and Rikiatu Husseini	Farming with the Forest: Agriculture and Conservation Synergy in Ghana's Western Wildlife Corridor	Gana
	19	14:30	Haruna Abukari*, Ziblim A. Imoro, Mathurin Zida, Amy Ickowitz and Rikiatu Husseini	Farming with the Forest: Agriculture and Conservation Synergy in Ghana's Western Wildlife Corridor	Gana
	20	14:45	Gabriel Plavan, Dilara K. Sunakbaeva*, Yaira Rakhmetova, Furkat Ubaev, Shamiran Salih Abdulrahman, Zeliha Selamoglu, Abdol Ghaffar Ebadi	Phytoremediation of Emerging Contaminants: Phytoremediating Pharmaceuticals, Microplastics, and PFAS	Romania
	21	15:00	Gabriel Plavan, Basim, S. A. A Sulivany, Fehmi Boufahja, Dilara K. Sunakbaeva, Abdol Ghaffar Ebadi*	Emerging Industrial Pollutants in Aquatic Systems: Monitoring, Risk Evaluation, and Green Remediation Strategies	Romania

Mola / Break
15:15 – 15:45

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Salon 1 – Hall 1
Oral Presentation – Online
Oturum Başkanı / Moderator: Ali Kaan Yetik

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
4. Oturum	22	15:45	Ouattara Souleymane, Kassankogno Abalo Itolou, Sérémé Abdoulaye3 and Koïta Kadidia1	In Vitro Comparative Activities of Four Essential Oils on Mycelial Radial Growth of Magnaporthe Oryzae B.C. Couch, a Rice Blast Pathogen in Burkina Faso	Burkina Faso
	23	16:00	Kouame Kohi Alfred; Tanoh Koffi Roger1	Postprocessing microflora of commercial soumbara (a fermented nere seeds product) produced in Côte d'Ivoire.	Côte d'Ivoire
	24	16:15	Gilles Léonce Niamketchi; Anauma Casmir Koko; Prince Junior Kanga; Kan Benjamin Kouamé2; Godi Henri Biego3	Physicochemical and nutritional values of tiger nut (Cyperus esculentus) oil from three regions of Côte d'Ivoire	Côte d'Ivoire
	25	16:30	Serhan Yeşilköy	Spatiotemporal Charactheristics in Climatic Extremes over Agricultural Lands in Türkiye	USA
	26	16:45	Danilo Yánez-Cajo1, Luis Godoy-Montiel, Ángel Cedeño-Moreira1, Ronald Villamar-Torres1, Fernando Cabezas-Guerrero1, Gregorio Vázconez-Montufar1, María Romero-Roman1 and Marco Heredia-Pinos1	Advancing Banana Cultivation Through Multispectral Imaging and Precision Agriculture: A Scalable Algorithm for Crop Optimization	Ecuador
	27	17:00	Ronald Villamar-Torres1*; Odalys Morán-Maffare1; Luis Godoy-Montiel1; Danilo Yánez-Cajo1; Ángel Cedeño-Moreira1; Marcos Heredia-Pinos1; Gregorio Vásconez-Montufar1; María Romero-Román1 and Milton Cabezas-Guerrero1*.	Machine Learning Techniques to Enhance Management and Decision-Making in Commercial Banana Plantations (Musa AAA) in Ecuador	Ecuador

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Salon 2 – Hall 2
Oral Presentation - Online
Oturum Başkanı / Moderator: Beyazıt Abdurrahman Şanlı

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
1. Oturum	1	09:00	Mary Angelar De Miguel*, Aimee Sheree Barrion	Knowledge Towards Food-Borne Parasitic Zoonoses and Self-Reported Hygiene Practices of Fish and Meat Vendors in the Public Market of Bay, Laguna	Philippines
	2	09:15	Raquel Oclarit-Salingay, Agripina Rana-Aradilla, Nenita B. Baldo, Ma. Stella M. Paulican	Foxtail Millet Setaria italica (L.): Acceptability of Indigenous Food Products Among the Mindanaoans, Philippines	Philippines
	3	09:30	Renato S. Pacaldo	Developing Short-Rotation Woody Biomass Feedstock in the Philippines: Strengths, Weaknesses, Opportunities, and Threats	Philippines
	4	09:45	Krishani Dharmasiri, Ruvini Mutucumarana, Manula Senanayake	Effect of Garlic Powder and Probiotic Supplementation on Growth Performance of Broiler Chickens	Sri Lanka
	5	10:00	Dileepa Shanthapriya, Ruvini Mutucumarana,Manula Senanayake	Effect of Paddy Straw and Wood Shavings as Alternative Bedding Materials for Broiler Chickens	Sri Lanka
	6	10:15	Kaveesha Chamodi Walawege, Ruvini Mutucumarana, Marcus Andrew	Assessing the Effect of Cassava Flour as a Binding Agent in Chicken Sausages	Sri Lanka
	7	10:30	R.M.C.R. Rajapaksha , K.K.B.S. Rajapaksha , A. Gunaratne , M. P. Edirisinghe, D. U. Rajawardana	Improvement of physicochemical and probiotic properties of frozen yoghurt by incorporating inulin and guar gum	Sri Lanka

Mola / Break
10:45 – 11:15

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Salon 2 – Hall 2
Oral Presentation - Online
Oturum Başkanı / Moderator: Beyazıt Abdurrahman Şanlı

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
2. Oturum	8	11:15	K.K.B.S. Rajapaksha*, M.A.L.S.S. Munasinghe, H.N.N. Dilrukshi, W.A.D. V. Weerathilake	Effect of plant-derived additives on bioactive properties of fermented dairy products: A review	Sri Lanka
	9	11:30	Anjela Oshadi Rodrigo, Thevagi Mahendran , Fathima Nuha Mohamed Ubaidullah	Extraction of Essential Oil from Sour Orange (Citrus aurantium) Peels and Evaluation of its Physico Chemical Characteristics	Sri Lanka
	10	11:45	Anjela Oshadi Rodrigo, Thevagi Mahendran, Fathima Nuha Mohamed Ubaidullah	Extraction of Essential Oil from Sour Orange (Citrus aurantium) Peels and Evaluation of its Physico Chemical Characteristics	Sri Lanka
	11	12:00	Nikshala Vanniyasingam*, Thiruchchelvan, N. and Mikunthan, G.	Biorationals in the Suppression of Sooty Mold Fungus, Capnodium spp. (Camille Montagne) established on the coconut whitefly honeydew	Sri Lanka
	12	12:15	Najib Altawell*, Batuhan Selamoglu, Koshanova Gulnazira Danebekovna, Zeliha Selamoglu, Abdol Ghaffar Ebadi	E-Waste Management in the Digital Age: Global Trends, Toxicological Risks, and Green Recovery Technologies	UK
	13				
	14				

Mola / Break
12:30 – 13:30

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Salon 2 – Hall 2
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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
3. Oturum	15	13:30	Melek Tuna, Fatmanur Çakıroglu, Fahriye Acar, Eda Adal, Tugba Aktar	Impact of Ultrasonication on Phase Separation and Sensory Attributes of Tahini: Ultrasonikasyonun Tahinin Faz Ayrımı ve Duyusal Özellikleri Üzerindeki Etkisi	Türkiye
	16	13:45	Muhammad Umair Asghar*, Qurat ul ain Sajid, Sible Canoğlulari Doğan	The Influence of Black Cumin Seed (Nigella sativa) Supplementation on Growth Performance, Carcass Characteristics, and Meat Quality in Poultry: A Comprehensive Review	Poland
	17	14:00	Dushimeyesu Erastus*, Edema Richard, Isiaka Abiodun, Uwimana Brigitte,	Advances in Molecular Breeding for Disease Resistance in Banana (Musa Spp): Current Trends and Future Prospects	Uganda
	18	14:15	Qurbanov Huseyn Nuraddin	Optımızıng the Constructıve Parameters of the Combıned Plough that Increases Productıvıty in Graın Farmıng	Azerbaycan
	19	14:30	Elbar Djenette, Rekis Abdelkrime, Elbar Chaima Yasmin	Combine Activated Carbon and Calcium Hydroxide to Lower the Salinity of Irrigation Water.	Algeria
	20	14:45	Souhila Mazguene	Fermented Foods and Human Health	Algeria
	21	15:00	Mounia Homranı	Antibacterial Effects of Imported (New Zealand) and Local Algerian Honeys Based on Botanical Origin	Algeria

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
4. Oturum	22	15:45	Hamza Belkhodja, Abderrahmane Remil, Fatima Zohra Labbaci, Djilali Bouhadi, Asmaa Belmimoun, Khadidja Sidelarbi	Evaluation of the Anti-inflammatory and Anti-hemolytic Potential of Polyphenolic Components of Common Mallow (Malva sylvestris)	Algeria
	23	16:00	Kebaili Hakimaa,*, Nouioua Wafaa, Dahamna Salihaa, Khennouf Seddika, Baghiani Abderrahmane b	Numidian fir tree (Abies numidica) role in the restoration of high mountain areas in Algerian forests	Algeria
	24	16:15	Chaıb Eddour Ahmed Readh*, Lıtım Miloud, Larbaouı Abdelkarim, Belhocıne Chaimaa, Bouderoua Kaddour	Characterization of Dried Orange Waste as a Valuable Ingredient in Broiler Chicken Diets	Algeria
	25	16:30	Hacene Fatima, Homranı Mounia, Homranı Abdelkader, Dahou Abdelkader Elamine	Investıgatıng the Phenotypıc Traıts and Probıotıc Potentıal of Lactobacıllus Autochthon	Algeria
	26	16:45	Boulgheb A.*, Azoua A.,Bedjaoui H., Boudali H., Abdelaali J.	Assessing genetic variability, heritability and genetic advance for yield and yield components in common wheat	Algeria
	27	17:00	Abdiaziz Hassan Nur*, Abdinasir Abdullahi Mohamed	GIS-Based on Assessment of Soil Erosion in Bay Region of Somalia	Somalia

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
1. Oturum	1	09:00	Akbar Hossain Tusher, Faysal Ahmed Himel, Babor Ahmad, Mostafa Monir, Md. Anowar Hossain	Comparison of Technical Efficiency between Boro Rice and Maize Production in the Northern Region of Bangladesh	Bangladesh
	2	09:15	Abdullahi Ali Ibrahim1, Md. Sadekur Rahman2 Md. Rubayet Al Ferdous Noman3	Perceıved Impact of Tea Farmıng on Lıvelıhoods of Smallholder Farmers in Panchagarh Dıstrıct	Bangladesh
	3	09:30	Mahmuod Abubakar Bashir,* and Md Shafiqul Bari,	Enhancing Food Productivity through Intensive Agroforestry Cropping for Sustainable Soil Practices – A Review	Bangladesh
	4	09:45	Md. Shakib Al Islam1, Mahabub Alam Ashik1, Arup Karmokar1, Md. Riyadh Arefin1,2*, A.K.M. Azad-ud-doula Prodhan1, A.K.M. Golam Sarwar1	Phytochemical Analysis of Selected Medicinal Plants Belonging to Family Fabaceae	Bangladesh
	5	10:00	Shittu, E.A., *Abdullahi, A., and Alobo, A.I	Optimizing Okra (Abelmoschus esculentus) Productivity through Integrated Nutrient Management: Effects of NPK Fertilizer and Cow Dung Manure in the Sudan Savanna, Nigeria	Nigeria
	6	10:15	Fatih Ramazan İstanbullugil	A Bibliometric Analysis on Food Waste and Sustainability in Central Asia	Kazakhstan
	7	10:30	Rose Sadykova*, Zeliha Selamoglu	Current Strategies in Pest Control Using Biological Agents	Kazakhstan

Mola / Break
10:45 – 11:15

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
2. Oturum	8	11:15	Ilesbekova Dinara*, Zeliha Selamoglu	Bee venom: A Natural Agent in the Treatment of Human Diseases	Kazakhstan
	9	11:30	Dilara K. Sunakbaeva*, Fehmi Boufahja, Najib Altawell, Basim, S. A. A Sulivany, Gabriel Plavan, Abdol Ghaffar Ebadi	Pollution to Solution: Nano-Enabled Strategies in Wastewater Treatment and Resource Recovery	Kazakhstan
	10	11:45	Adil Hussain, Muhammad Daniyal Junaid, Javaria Tabassum, Muhammad Arshad Javed	Hıgh-Throughput Phenotypıng of Exotıc Tomato Germplasm for Fruıt Sıze, Shape, and Color Dıversıty	Pakistan
	11	12:00	Misbah Iqbal1, Raheela Waheed2, Roomina Mazhar3, Safa Akhtar4, Farah Deeba1*	Green Synthesis of ZnO, CuO and ZnO-CuO Nanoparticles from Nigella sativa L. Extract and Effect of Nanoseed priming on Chickpea under Salinity Stress	Pakistan
	12	12:15	Muhammad Awais Ahmed1, Muhammad Arshad Javed1, Javaria Tabassum1, Muhammad Asad Ullah1	Integrative Genomic and Transcriptomic Analysis of GASA Gene family in Sunflower Reveals Their Regulatory Role in Drought Stress Response	Pakistan
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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
3. Oturum	15	13:30	Victoria Folakemi Akinjogunla*, Mohammed Sani Isiyaku and Gideon Echiepu Adeno	Assessment of Selected Heavy Metals in Water, Sediment and Muscles of Some Edible Finfishes - Schilbe mystus, Sarotherodon galileus, Mormyrus rume and Clarias anguillaris from Ajiwa Irrigation Dam, Katsina State, Nigeria	Nigeria
	16	13:45	Tasiu, Y. G., Alalade, O.M., Atiku, M.K and Dawi, A. W	Productıon And Qualıty Evaluatıon Of Artısan Spaghettı Incoporated Wıth Xanthan Gum And Eggs	Nigeria
	17	14:00	1e.A. Shıttu., 2m. S. Basse., & V. N. Racha	Sustainable Cowpea (Vigna unguiculata L.Walp) Production as Impacted by Integrated Weed Management Practices	Nigeria
	18	14:15	Muhammed, H.M*, 1Stephen, D.Y., Muhammad, M.I, Ndayako, H. H., Mohammed, R. S. and Yahaya, I.,	Effect of Some Packagıng Materıals on Seed Vıabılıty Of Arachis Hypogaea L (Groundnut)	Nigeria
	19	14:30	Yahaya Zira Dia and Daniel Stephen Oaya	Determinants of Poverty Among Rural Farming Households in Ganye Local Government Area of Adamawa State, Nigeria.	Nigeria
	20	14:45	Hakeem, I.*, Jiya, E.Z., Adama, J.Y. and Alabi, O.J., Olusegun, M. A., Ridwan O.I.	Evaluatıon of the Antıoxıdant Potentıals of Fruıt Peels Extract	Nigeria
	21	15:00	Ogunbosoye D.O, Afe A.I, Raji A, Imam R.O and Magaji G	In vitro and ruminal characteristics of the three selected Nigerian herbs: Phyllantus amarus, Ocimum gratissimum and Lactuca taraxacifolia as feed additives in ruminant production	Nigeria

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
4. Oturum	22	15:45	Roland Mecaj, Majlınd Sulce, Florıan Plaku, Gerı Muca, Renıs Maçı, Enkelejda Sallaku, Etleva Delıa, Xhelıl Kolecı & Myqerem Tafaj*	Development of a Practical Model to Evaluate the Influence of Abiotic Factors on Subclinical Mastitis in Dairy Farms in Albania	Albania
	23	16:00	Majlınd Sulçe*, Roland Meçaj, Renıs Maçı, Florıan Plaku, Enkelejda Sallaku, Etleva Delıa, Xhelıl Kolecı & Myqerem Tafaj	The impact of mineral nutrition, udder hygiene, and housing practices on subclinical mastitis under production conditions in Albanian dairy farms	Albania
	24	16:15	Ezgi Aksakallı, Müberra Koşar, Fatih Demirci	The role and potential of in silico studies in medicinal plant research	Cyprus
	25	16:30	Nardin Sedghizadeh, Emre Hamurtekin, Ezgi Aksakallı	Cardioprotective Effects of Crocus sativus L. Against Doxorubicin-Induced Cardiotoxicity: A Review of Antioxidant and Anti-Apoptotic Mechanisms	Cyprus
	26	16:45	Melis Yağlı, Gülay Demir, Hasan Eleroğlu	Broyler Yetiştiriciliğinde Kullanılan Yem Katkı Maddelerinin Et Kalitesi Üzerine Etkilerinin Bibliyometrik Analizi	Türkiye
	27	17:00	Veli Vural Uslu,, Ramazan Beyaz	Gene Deletions and Silencing via High Pressure Spraying Technique	Germany

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
1. Oturum	1	09:00	Imam Muhyidiyn*, Mohammad Sohidul Islam, Mahmuod Abubakar Bashir	Restoring Agroecosystem Biodiversity: The Role of Regenerative Farming in Reversing Monoculture-Induced Declines	Bangladesh
	2	09:15	Rayhan Kabir, Saiful Huda, Abu Mondol and Rubayet Noman	Constraints in Aromatic Rice Cultivation: Insights from Smallholder Farmers of Northern Bangladesh	Bangladesh
	3	09:30	Rubayet Noman, Rayhan Kabir, Saiful Huda, Abu Mondol	Constraints in Aromatic Rice Cultivation: Insights from Smallholder Farmers of Northern Bangladesh	Bangladesh
	4	09:45	Merin Monira Khanam, Karmokar Arup, Hossain AKM Zakir, Ashrafuzzaman Md	Phytochemical and Antioxidative Properties of Kaempferia Species Found in Bangladesh	Bangladesh
	5	10:00	Şehnaz Özatay	Biodegradable Materials Production from Food Waste: A Sustainable Approach	Türkiye
	6	10:15	Şehnaz Özatay, Çağlar Kaya	The Effects of Functional Foods on Human Health	Türkiye
	7	10:30	AKM Quamruzzaman	Utrıtıon-Focused Evaluatıon of Tomato Lınes for Sustaınable Food Systems in Bangladesh	Bangladesh

Mola / Break
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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
2. Oturum	8	11:15	Uwisize, M. G., Verma, M. K., Sahoo T., Singh, S.K. and Sethi, S.	Effect of Gibberellin acid on Mechanical and Morpho-physical properties of Seedless grapes	India
	9	11:30	Fasina, O.O. and Adewale, M.D.	Level of Utilization of Agritech Services by Rice Farmers in Niger State, Nigeria	Nigeria
	10	11:45	*1Moses Samuel Bassey, and 2Emmanual Abraham Shittu	Productivity, Water use efficiency, Soil properties of Sugarcane as influenced by trash mulching and weed management practices under dry season conditions in Nigeria	Nigeria
	11	12:00	O.O. Fasina and T.K. Olafisoye	Protective Community Index as a Measure for Child Labour: A Case Study of Cocoa-Producing Communities in Idanre Local Government Area, Ondo State	Nigeria
	12	12:15	Olayemi R. Awodoyin and Oluwatobiloba D. Oyekunle	Garlic and Ginger Pastes as natural Antioxidant in Spent Hen Meat Nugget	Nigeria
	13				
	14				

Mola / Break
12:30 – 13:30

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
3. Oturum	15	13:30	Saba Zafar1 , Rehan Sadiq Shaikh2	Identification of Novel TMC1 and TECTA Mutations in the Pakistani Population: Insights into the Genetic Basis of Hearing Impairment	Pakistan
	16	13:45	Duygu Aslan Türker	Interfacial Activity and Stabilization Mechanisms of Food Colloids in Pickering Emulsions	Türkiye
	17	14:00	Said Muhammed1, Cem Tokatlı2	Comparative Analysis of Water Quality in Dam Lakes of Edirne Province, Türkiye	Pakistan
	18	14:15	Muhammad Iqbal	Immobilizing Pb in soil polluted with Pb batteries effluents: Confirmation at biological and chemical scales	Pakistan
	19	14:30	Çağlar Kaya	Bitkisel Üretimin İklim Değişikliğinden Etkilenebilirliği ve Çözüm Önerisi Olarak Modern Biyoteknolojik Yaklaşımlar	Türkiye
	20	14:45	Said Muhammed, Cem Tokatlı	Assessing Contamination Risks in Sultanköy and Altınyazı Reservoirs (Türkiye) Using Modified Organic Pollution Indices	Pakistan
	21	15:00	Maqsood Ali Wagan, Niaz Ahmed Wahocho, Maria Abro, Ghulam Hussain Wagan, Farhan Ali Wagan	Effect of Moringa Leaf Lxtract (MLE) on Sprouting and Growth Responses of Stem Cuttings of China rose (hibiscus rosa- sinensis l.)	Pakistan

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
4. Oturum	22	15:45	Muhammad Umair Asghar1,*, Qurat ul ain Sajid1, Mariusz Korczyński1, Sibel Canoğulları Doğan2	Enhancing Poultry Nutrition with Hydrobarothermal-Treated Non-GMO Soybean Meal: A Sustainable Approach	Poland
	23	16:00	1Usman Muhammad Umar, 2Zeynep Ünal, 3Osman Elwasila, 3Yonis Gulzar,	The Impacts of Precision Technologies on Cropping System in Developing Countries: A Case Study for Nigeria	Saudi Arabia
	24	16:15	Fehmi Boufahja1, Basim, S. A. Al Sulivany2, Shamiran Salih Abdulrahman2,3, Yaira Rakhmetova4, Muhammad Yasir Naeem5*, Zeliha Selamoglu6,7	Beyond Green Barriers: Genetic Engineering Progress toward Enhanced Phytoremediation Efficiency	Saudi Arabia
	25	16:30	Fehmi Boufahja1, Gabriel Plavan2, Tulkinzhon Gaipov3, Rzgar Farooq Rashid4*, Dilara K. Sunakbaeva5, Najib Altawell6	Geohealth Frontiers: Linking Geological Substrates to Public Health and Ecosystem Risk Assessment	Saudi Arabia
	26	16:45	Merve Oğuz*, Soner Soylu1, Yusuf Gümüş1	Investigation of in vitro Antibacterial Potential of Various Wood Vinegars Against Plant Bacterial Disease Agents	Türkiye
	27	17:00	Muhammed Zahid Kasapoglu*	Effects of Different Drying Methods and Temperatures on the Bioactive Compounds in Purple Carrot Extracts	Türkiye

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
1. Oturum	1	09:00	Akm Quamruzzaman*, L. Akter, Mr Islam, S. Akter And Mh Islam	Advancıng Tomato Hybrıd Development: Yıeld Evaluatıon Of Wınter-Grown Hybrıds In Bangladesh	Banglades h
	2	09:15	Ariful Haque1, Sadekur Rahman2, And Rubayet Noman3	Farmer's Attitude Towards Rental Combine Harvester İn Thakugaon District	
	3	09:30	Akm Quamruzzaman*, M. Nazim Uddin, L. Akter, M. S. Hossain And S. Ahmad	A Business Model For Community-Based Vegetable Seed Production İn Bangladesh	Banglades h
	4	09:45	L. Akter, Akm Quamruzzaman*, S. Akter And Mh Islam	Acceleratıng Sweet Pepper Improvement: Inbred Lıne Development For Bangladeshı Varıetıes	Banglades h
	5	10:00	Tanvir Ahamed Niloy1 Arup Karmokar2, Md. Riyadh Arefin2,3, Phalguni Das1, Protyasha Biswas1, Mousumi Akter1, Md. Zakir Hossen1, A.K.M. Golam Sarwar2, Md. Shohidul Alam1*	Impact of Biochemical and Physicochemical Properties on the Organoleptic Attributes of Tea from Different Regions of Bangladesh	Banglades h
	6	10:15	L. Akter, Akm Quamruzzaman*, Mr Karım, S. Akter And Mh Islam	Productıvıty And Nutrıtıonal Potentıal Of Sweet Pepper Varıetıes In Bangladesh	Banglades h
	7	10:30	Md. Solayman Ope, Sumaia Sultana, Samir Shakir and M. Ashrafuzzaman	Nutritional, Medicinal, and Industrial Applications of Tokma (Hyptis suaveolens), Isabgol (Plantago ovata), and Chia (Salvia hispanica): A Comprehensive Review	Banglades h

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
2. Oturum	8	11:15	Akm Quamruzzaman*, L. Akter, Mr Islam, S. Akter And Mh Islam	Selection Of High-Yielding Watermelon Lines For Enhanced Food And Nutritional Security İn Bangladesh	Bangladesh
	9	11:30	Abdulhamid Muhammad Garba, Sema Yaman Fırıncıoğlu	The Applıcatıon Of Tannın's In Rumınant Nutrıtıon (A Revıew)	Nigeria
	10	11:45	*Adebayo Samson Adeoye, Adebayo David Samuel	Assessing The Contribution Of Musa Species To Sustainable Livelihoods Of Agroforestry Farmers İn Egbeda Municipality, Oyo State, Nigeria	Nigeria
	11	12:00	Joy Chiamaka Echebiri, Gabriel Oladele Awe, Toyin Peter Abegunrin, Emmanuel Eniola Afolabi	Cover Crop Biomass And Organic Manure Applications For İmproved Soil Physico-Chemical Properties And Tomato Yield İn A Continuous-Cropped Arable Land.	Nigeria
	12	12:15	Yusuf Shafiu Yusuf, Sibel Canoğulları Doğan	Sustainable Feed To Reduce The Environmental Impact Of Poultry Production	Nigeria
	13				
	14				

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
3. Oturum	15	13:30	Raed Shehata	Eating Fresh Strawberry Fruits Free from Pesticide Residues by Using 28-Homobrassinolide.	Egypt
	16	13:45	Hussein, A,M1.; Farrag, F.H.; El- Arian, M.N.; Omer. E.A1. and Khattab, A.S.	A comparison of different selection indexes for milk traits in Friesian cows by using different relative economic values.	Egypt
	17	14:00	Alemayehu Arega*, Girma Chalchisa and Abdela Edao	Evaluation of ensiled brewery spent grain as a substitute for protein source concentrate in the diet of Lactating crossbred dairy cows at Adami Tullu Agricultural Research Center	Ethiopia
	18	14:15	Usman Mohammed Ali*	Evolution and Transformation of Ethiopian Agriculture: A Review of Historical Trends, Contemporary Challenges, and Future Opportunities	Ethiopia
	19	14:30	Esubalew Abate Alemu	Ethiopia's Livestock Production and its Contribution to Food Security	Ethiopia
	20	14:45	Alemayehu Arega*, Tesfaye Alemu Aredo and Sisay Eshetu	Effects of sexed semen on fertility and sex ratio of calves in indigenous Arsi Cattle at Adami Tulu Agricultural Research Center	Ethiopia
	21	15:00	Mehmet Zahit Demir, Hasan Eleroğlu	Serbest ve Zenginleştirilmiş Kafes Sisteminin Yumurta Mineral Madde Ve Yağ Asitleri İçeriğine Etkisi	Türkiye
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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
4. Oturum	22	15:45	Melese Ageze Mihretu	Effects of Parboiling on Cooking Qualities of the Super Green Rice Variety Grown in Ethiopia	Ethiopia
	23	16:00	Bantewalu Hailekidan Dukamo*, Andargachew Gedebo Abitie Hewan Demissie Degu Bizuayehu Tesfaye Asfaw	Assessment of Stress-Adaptative Traits in Durum Wheat (T. turgidum subsp. durum) Landraces Using Agromorphological, Physiological, and Proline Content Parameters	Ethiopia
	24	16:15	Rzgar Farooq Rashid*, Mesut Selamoglu	Ecological Logistics Approaches: Supply Chain Strategies for Biodiversity Conservation	Iraq
	25	16:30	Shamiran Salih Abdulrahman1,2, Muhammad Yasir Naeem3*, Dilara K. Sunakbaeva4, Yaira Rakhmetova5, Abdol Ghaffar Ebadi6	Constructed Wetlands and Aquatic Phytoremediation: Nature-Based Solutions for Water Purification	Iraq
	26	16:45	Basim, S. A. Al Sulivany1, Fehmi Boufahja2, Gabriel Plavan3, Dilara K. Sunakbaeva4*, Abdol Ghaffar Ebadi5	Nanotechnology-Assisted Phytoremediation: A Hybrid Strategy for Superior Contaminant Removal	Iraq
	27	17:00	Albulene Emini*, Osman Seyyar, Hakan Demir	Comparison of Setae Morphology of Both Sexes of Oxyopes ramosus (Martini & Goeze, 1778) (Araneae, Oxyopidae)	Kosovo

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
1. Oturum	1	09:00	Maqsood Ali Wagan, Niaz Ahmed Wahocho, Maria Abro, Ghulam Hussain Wagan, Farhan Ali Wagan	Effect of Moringa Leaf Lxtract (MLE) on Sprouting and Growth Responses of Stem Cuttings of China rose (hibiscus rosa- sinensis l.)	Pakistan
	2	09:15	Maqsood Ali Wagan, Niaz Ahmed Wahocho, Maria Abro, Farhan Ali Wagan,	Effect of different level of macro nutrients on the growth and development of spinach (Spinacia oleraceae L.)	Pakistan
	3	09:30	Maria Abro, Uzma Arif, Hube Ali Magsi, Narjis Abro, Maqsood Ali Wagan	Integrated use of Fertilizers and Bio-Stimulant affect the Growth and Seedling Development of Chili	Pakistan
	4	09:45	Maria Abro, Uzma Arif, Hube Ali Magsi, Narjis Abro, Maqsood Ali Wagan	Morphological Characterization of Common bean (Phaseolus vulgaris L.) Genotypes at Early Growth Stage	Pakistan
	5	10:00	Shazia Batool1, Laaraib Nawaz2*	Ameliorative Effects of Citrus limetta raw juice on Cyclophosphamide-Induced Organ Toxicity in Rats	Pakistan
	6	10:15	Irfana Parveena; Kousar Parveena*; Saira Mansaba	Geospatıal analysıs and quantıfıcatıon of bıoaccumulated pollutants ın fresh mılk	Pakistan
	7	10:30	Wajid Khan*1, Asad Ullah1, Asif Nawaz1, Muhammad Nazir Uddin1 and Nabila Qayum1	Evaluation of antibacterial efficacy of albedo of Citrus medica fruit against pathogenic microorganisms	Pakistan

Mola / Break
10:45 – 11:15

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
2. Oturum	8	11:15	Muhammad Farhan Jahangir Chughtai1, M. Naveed Aslam1, Samreen Ahsan1, Atif Liaqat1, Tariq Mehmood1, Adnan Khaliq1 and Kanza Saeed1,2.	Comparatıve Analysıs of Dryıng Technıques to Assess the Shelf Lıfe Extensıon of Apple Varıetıes	Pakistan
	9	11:30	Hafiza Malaika Choudhary1, Syeda Areej Imran1, Munawar Ali1*, Muther Mansoor Qaisrani1, Kashif Kareem1	Understanding Molecular Mechanisms: Recent Advancements in Plant Resilience to Drought and Salinity	Pakistan
	10	11:45	Kubrat A. Oyinlola*1, Rosemary O. Ogundola1 and Gbemisola E. Ogunleye2	Biosynthesis, production optimization and antifungal property of indole-3-acetic acid from Pseudomonas aeruginosa ROO1S	Nigeria
	11	12:00	Ridwan Mukaila1*, Festus Eluwande Awoyelu2, Ibrahic Isaac Umaru3	Understanding Farmers' Stated Preference for Gold-Mined Degraded Land Restoration	Nigeria
	12	12:15	O. I. A. Oluremi, P. K. Shighe, N. C. Anom, O. S. Gabriel and M. A. Mahlehla	Utilisation of Bovine Rumen Filtrate for Biodegradation of Sweet Orange Peel (Citrus sinensis) and Effect on Rabbit Performance	Lesotho
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Mola / Break
12:30 – 13:30

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Oturum Başkanı / Moderator: Ali Kaan Yetik

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
3. Oturum	15	13:30	Mohammad Abed, Ayed Sourout, AyarlarSharaf Al-Tardeh	Effect of Nanoparticles Application on the Germination and Growth of Tunisian Durum Wheat Varieties (Dhabee, Kareem and Inrat100) Under Simulated water Stress Conditions	Tunusia
	16	13:45	Fredrick Alleni Mfinanga, Barakael Israel Panga Jacqueline Temba	Enhancing Cotton Yield through Adoption of Climate Smart Agriculture: A Case of Smallholder Farmers in Bariadi District, Tanzania	Tanzania
	17	14:00	Bihter Cebeci*, Senem Kamiloglu	Recent Advances on the Effect of Cold Plasma Treatment on Carotenoids	Türkiye
	18	14:15	Ramil Jr. Entana	Growth Performance of Broiler Chicken (Gallus gallus domesticus) in Response to Cinnamon Powder as Feed Additives	Philippines
	19	14:30	Oyetoro John Oyewole, Ayandele Ayanbukola Oluwaseun, Adewole William Adekunle Sotola Abiodun Emmanuel Oyedele Temitope Charles, And abdulrauf Abdulwahab	Utılızatıon Of Urban Agrıcultural Practıces In Osogbo Metropolıs Osun State, Nıgerıa	Nigeria
	20	14:45	Yusuf Shafiu Yusuf, Sibel Canoğulları Doğan	The Role Of Genomics İn Improving Egg And Meat Production	Nigeria
	21	15:00	Ogunleye Gbemisola E, Omirin Samuel, Oyinlola Kubrat A, Olatoye Motunrayo J. Fashogbon Racheal	Phytochemıcal Screenıng And Inhıbıtory Actıvıtıes Of Synthesısed Sılver Nanopartıcles From Cıtrus Sınensıs Peel Agaınst Some Selected Pathogens	Nigeria

Mola / Break
15:15 – 15:45

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
4. Oturum	22	15:45	Muhammad Yasir Naeem1*, Batuhan Selamoglu2, Abdol Ghaffar Ebadi3	Next-Generation Bioelectrochemical Systems: Bridging Synthetic Biology and Green Electronics to Harvest Renewable Energy	Italy
	23	16:00	Muhammad Yasir Naeem1*, Batuhan Selamoglu2, Abdol Ghaffar Ebadi3, Mesut Selamoglu4	Decarbonizing Development: Integrated Renewable Energy Models for Climate-Smart Transitions in Emerging Economies	Italy
	24	16:15	Nasser Beikzadeh1*, Afshin Hassani-Mehraban2 and Seyyed Fazel Fazeli Kakhki1	Detection of Tomato Yellow Ring Orthotospovirus in North Khorasan Province, Iran	Iran
	25	16:30	Aidin Azizpour	Prevalence and antibiotic resistance of Staphylococcus aureus isolated from commercial poultry carcasses in Ardabil province, Iran	Iran
	26	16:45	Abdol Ghaffar Ebadi1*, Tulkinzhon Gaipov2	Beyond Waste: Integrative Biotechnological Pathways for Sustainable Recycling and Valorization of Industrial and Domestic Residues	Iran
	27	17:00	Mahsa Ebadi1*, Mahboubeh Babaee2, Gabriel Plavan3, Tulkinzhon Gaipov4, Shamiran Salih Abdulrahman5,6	The Psychology of Nature Connection: How Environmental Education Develops Ecological Empathy and Action	Iran
		17:15	Bekir Ayyıldız, Tuğrul Yakuoğlu	Paris İklim Anlaşması Çerçevesinde Tarımsal Karbon Ayak İzi, Çevresel Baskılar ve Azaltım Politikaları: Türkiye ve Avrupa Birliği Karşılaştırması	Türkiye
		17:30	Senem Dobur, Bekir Ayyıldız, Hilmi Erdal	Küresel Perspektiften Türkiye'ye: Tarım Ekonomisinde Yeşil Yaka Uygulamaları Üzerine Bir Derleme	Türkiye

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
1. Oturum	1	09:00	Leyla İdikut*, Elif Evcimen	Farklı Azot Dozların Ekmeklik Buğdaya Çeşitlerinin Kalite Kriterlerine Etkileri	Türkiye
	2	09:15	Leyla İdikut*, Enes Hakan Seçilmiş	Mısır Bitkisinde Yaprak Uzaklaştırmanın Koçan Özelliklerine Etkisi	Türkiye
	3	09:30	Muhammad Yasir Naeem1*, Furkat Ubaev2, Zeliha Selamoglu3,4	Agri-Pharma-Food Nexus: Harnessing Edible Plants as Bio-factories for Next-Gen Pharmaceuticals	Italy
	4	09:45	Muhammad Yasir Naeem1*, Dilara K. Sunakbaeva2, Yaira Rakhmetova3, Abdol Ghaffar Ebadi4	Rooted Solutions: Rhizosphere Microbiome Synergies in Phytoremediation of Contaminated Soils	Italy
	5	10:00	Abdol Ghaffar Ebadi*, Yaira Rakhmetova, Zeliha Selamoglu	Resistant Microbial Consortia in Contaminated Communities: Ecological Processes, Genomic Insights, and Biotechnological Prospects	Iran
	6	10:15	Abdol Ghaffar Ebadi*, Usman Mir Khan, Muhammad Yasir Naeem, Umar Murad Khan, Yaira Rakhmetova, Ali Murad Khan	Bio-Transformation of Agricultural and Municipal Waste into High-Value Resources: Advances, Challenges, and Future Prospects	Iran
	7	10:30	Usman Mir Khan, Abdol Ghaffar Ebadi*, Muhammad Yasir Naeem, Zeliha Selamoglu	Molecular Detection and Detoxification of Aflatoxins: Recent Advances in Biotechnology and Nanomaterials	Pakistan

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
2. Oturum	8	11:15	Muhammad Yasir Naeem1, Najib Altawell2*, Tulkinzhon Gaipov3, Dilara K. Sunakbaeva4, Abdol Ghaffar Ebadi5	Hyperaccumulators Redefined: Innovation in Phytoextraction and Phytomining for Resource Recovery	Italy
	9	11:30	Muhammad Yasir Naeem1*, Yaira Rakhmetova2, Dilara K. Sunakbaeva3, Abdol Ghaffar Ebadi4	Phytoremediation and Soil Health: Restoring Microbial Diversity and Functionality in Degraded Lands	Italy
	10	11:45	Mahsa Ebadi1*, Mahboubeh Babaee2, Furkat Ubaev3, Muhammad Yasir Naeem4, Tulkinzhon Gaipov5, Shamiran Salih Abdulrahman6,7	Green Minds, Greener Futures: Integrating Ecopsychology into Environmental Curricula for Holistic Sustainability	Iran
	11	12:00	Abdol Ghaffar Ebadi1*, Najib Altawell2, Mesut Selamoglu3, Gabriel Plavan4	Climate Change and the Caspian Sea Basin: Hydrological Alterations and Socio-Ecological Impacts	Iran
	12	12:15	Muhammad Yasir Naeem, Dilara K. Sunakbaeva, Usman Mir Khan*, Yaira Rakhmetova	Regenerative Soil Management in Agriculture: Unleashing Carbon Sequestration and Climate Mitigation Potential	Italy
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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
3. Oturum	15	13:30	**Oluwadurotimi O. Akintade**1*, Kehinde A. Oyegoke1, Fausat O. Odujebe1, Grace O. Ayorinde1	Analysis of Heavy Metals in Soil and Medicinal Plants (Bryophyllum Pinnatum[BPi] and Vernonia Amygdalina [VA]) using Risk Assessment Indices	Nigeria
	16	13:45	Oyetoro, J.O., Tiamiyu A.O, Adebayo, R.A. and Sotola, A. E.	Effect Of Global Allıance For Improved Nutrıtıon (Gaın) Technology Transfer On Nutrıtıonal Status Of Sweet Potatoes Farmers In Oyo State Nıgerıa	Nigeria
	17	14:00	Adio, M. O., Oyebamiji, I. T., Oloniyo, R. B., and Olaoye, T. A.	Assessment Of Food Securıty Among Cocoa Farmıng Households In Osun State, Nıgerıa	Nigeria
	18	14:15	Samson Oluwaseyi Afolayan, Lois Toluwani Akinjobi ,Onabanjo Oladipupo Akande ,Balogun	Preference and Purchasıng Behavıour of Selected Functıonal Foods Among Households in Ifo Local Government Area, Ogun State, Nıgerıa	Nigeria
	19	14:30	Abdulrashid I., R.B Mukhtar, H. Bilyaminu, A. Abubakar, A. Auwal and M. S. Gude	Effect Of Pre- Sowıng Seed Treatment Of Morınga (Moringa Oleifera) On Sandy Loam Soıl	Nigeria
	20	14:45	Yusuff Lawal, Oluwadare Adebisi	AI and IoT-Based Smart Irrigation: A Review of Challenges and Future Trends	Nigeria
	21	15:00	Rachael Abiola, Adetutu Habib , Lois Akinjobi , Grace Tayo	Awareness, Perceıved Effect and Mıtıgatıon Strategıes on The Effect of Clımate Change Among Poultry Farmers in Ogun State of Nıgerıa	Nigeria

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
4. Oturum	22	15:45	Musa Kose1*, Kuyu Kongas 1	Climate change and livestock production in Africa	Sudan
	23	16:00	Musa Kose	Water resources management and climate change in South Sudan	Sudan
	24	16:15	T. F. Ojo* and B. F. Balogun,	Bridging the Digital Divide: An Assessment of Agricultural Extension Personnel's Usage of Digital Technology in Ondo State, Nigeria	Nigeria
	25	16:30	*Dawı, Amın Wakawa&; Nouruddeen, Zahra'u Bamallı And Alkasım Kabıru Yunusa; Banıgbe Shade Abıgaıl	An Overvıew On Fısh Smokıng, Nutrıtıonal Qualıty, Wood Bıomass, And Theır Effects On Health	Nigeria
	26	16:45	Osman Sabri Kesbiç, Hilal Metin, Ümit Acar And Hüseyin Serkan Erol	A Natural Solution Against Fish Oil Oxidation: The Antioxidant Effect of Satureja montana Essential Oil	Türkiye
	27	17:00	Hüseyin Serkan Erol, Hilal Metin, Ümit Acar and Osman Sabri Kesbiç	Prevention of Fish Oil Oxidation by Melaleuca quinquenervia Essential Oil: Dose Dependent Antioxidant Effects	Türkiye

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
1. Oturum	1	09:00	Mst. Adia Sultana1, Shobnom Mustary1 , Maisha Rahman1, Tahmina Akter1, Md. Rezwanul Haque1, Md. Arif Sakil1*	Effects of Allantoin, A Stress-related Purine Metabolite, on Salt Stress Mitigation in Maize (Zea mays L.) During Early Germination Stage	Bangladesh
	2	09:15	Md. Abu Tasfar Bin Sowad, Abdullah Zinnurain Bin Ashraf1A.K.M. Anisur Rahman2 and M. Ashrafuzzaman	Bangladeshi Medicinal Plants with Anthelmintic Potential: A Scoping Review	Bangladesh
	3	09:30	Saudah Binte Ashraf, Md Ruhul Amin and Md Shahjahan	Unveiling the role of spirulina in the mitigation of sumithion-induced toxicity in Thai pangas, Pangasianodon hypophthalmus	Bangladesh
	4	09:45	Md Ruhul Amin, Saudah Binte Ashraf, Mst Nusrat Jahan, Md Shahjahan*	Ameliorative Role of Dietary Spirulina platensis on Sumithion-Induced Growth Suppression and Intestinal Histopathological Alterations in Striped Catfish (Pangasianodon hypophthalmus)	Bangladesh
	5	10:00	Mahadi Amin1, Md Shahjahan1	Amelioration of Microplastics-Induced Growth Inhibition and Stress in Nile Tilapia Using Multi-Species Probiotic	Bangladesh
	6	10:15	A.K.M. Afzal Hossain1, Md. Abu Rahad1, Md Al-Emran1, Md Mahiuddin Zahangir2, Md Shahjahan1*	Ameliorative Role of Spirulina on Sumithion-Induced Hematological and Molecular Altarations in Nile tilapia	Bangladesh
	7	10:30	Shakil Ahmed1, Md Shahjahan1	Impacts of Salinity Stress on the Physiology and Tissue Structure of Nile Tilapia	Bangladesh

Mola / Break
10:45 – 11:15

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
2. Oturum	8	11:15	Murat Özocak, Can Burak Şişman	Determination of Heating Potential with Geothermal Energy in Greenhouses in Kırklareli Province	Türkiye
	9	11:30	Usman Mir Khan1*, Mesut Selamoglu2	Traceability in Food Logistics: From Farm to Fork	Pakistan
	10	11:45	Hosameldeen Mohamed Husien, Majdoleen Ahmed Mohammed, Ahmed A. Saleh, Mohamed Osman Abdalrahem Essa, Saber Y. Adam, Elsir Abdelhai Babiker and Mengzhi Wang*	Impact of Varying Moringa oleifera Leaf Diets on Productive Performance and Reproductive Characteristics of Nubian Goats	Sudan
	11	12:00	Usman Mir Khan1*, Muhammad Yasir Naeem2, Zeliha Selamoglu3,4, Abdol Ghaffar Ebadi5	Bioremediation of Aflatoxins: Harnessing Microbial and Enzymatic Tools for Mycotoxin Degradation	Pakistan
	12	12:15	Usman Mir Khan, Muhammad Yasir Naeem5, Yaira Rakhmetova3, Tulkinzhon Gaipov	Climate-Smart Agriculture and Soil Resilience: Strategies for Arid and Semi-Arid Regions	Pakistan
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	14				

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
3. Oturum	15	13:30	Iqtidar Hussain	Application of Different Phytosolutions on Germination and Growth Indices of Wheat	Pakistan
	16	13:45	Abdalla Hassab Elrasoul, Ahmed Ibrahim, Ibrahim Musa Tibin	Effect of Adding Camel Hump Fat on Quality Attributes of Beef Burger	Sudan
	17	14:00	Fredrick Onyango Ogutu,*; Boniface Oure, Winstone Asugo Nayguti, Obong'o, Christine Wanja Maringa, Agatha Kemunto, Tai-Hua Mu* Hongnan Sun; Alfred Anakalo Shitandi	Characterisation and Antioxidant Activity of Pectin from Sweet Potato Starch Extraction Residues	Kenya
	18	14:15	Lydia Akinyi Omondi	Determınants Of Choıce Of Marketıng Outlet For Edıble Insects Among Smallholder Farmers And Traders In Western Kenya	Kenya
	19	14:30	Fredrick Onyango Ogutu1*, Boniface Oure1, William Mutwiri Thari2, Johnstone Kibet Lang'at2, Winstone Asugo Nyaguti4, Gertrude M. Okiko1, Japheth Anuro1, Christine W. Maringa1	Nutritional Composition of Hass Avocado (Perseaamericana Mill) Cultivated in Major Growing Areas in Kenya	Kenya
	20	14:45	Winstone Asugo, Rose Mboya, Simbi Mark Evance, Lilian Kathambi	Situational Analysis of Kenyan Slaughterhouses in Relation to Resource Utilization. The Case of Nairobi County.	Kenya
	21	15:00	T. F. Ojo* and B. F. Balogun,	Bridging the Digital Divide: An Assessment of Agricultural Extension Personnel's Usage of Digital Technology in Ondo State, Nigeria	Nigeria

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
4. Oturum	22	15:45	Winstone Asugo, Francis Polong, Rose Mboya, Patrick Sifa, Simbi Mark Evance, Lilian Kathabi	Resource Mapping and Economic Potential Assessment of Turkana County, Kenya	Kenya
	23	16:00	*Dawı, Amın Wakawa&; Nouruddeen, Zahra'u Bamallı And Alkasım Kabıru Yunusa; Banıgbe Shade Abıgaıl	An Overvıew On Fısh Smokıng, Nutrıtıonal Qualıty, Wood Bıomass, And Theır Effects On Health	Nigeria
	24	16:15	Banıgbe Shade Abigael; *Dawı, Amin Wakawa; Adebıyı, Olubodun Ayodeji And Tahır, Hayfa Zubair.	Proxımate And Phytochemıcal Propetıes Of Bread Prodcued From Pro-Vıtamın A Rıch Cassava, Afrıca Walnut And Tıgernut Composıte Blends	Nigeria
	25	16:30	Emmanuel Ugochukwu Anaso	Body Thermoregulatory Adaptatıons And Reproductıve Potentıals Of Yankassa Rams Fed Dıets Contaınıng Urea-Molasses Treated Cassava Peel Ensıled Wıth Caged-Layer Droppıngs	Nigeria
	26	16:45	*Samuel Preye Jimmy 1, Julius Emeka Omeje 2 and Funlayefa Adokeme1	Fish farmers' choice of adaptation strategies to climate change in Bayelsa State	Nigeria
	27	17:00	*Abdulwahab, F.S.1, Abdullahi, S.2 Aliyu, A.S.1, Danguguwa, D.D.3 and Iliyasu, A.B.4	Strengthening Farmer-to-Farmer Knowledge Sharing Networks: A Pathway to Improved Agricultural Extension Service Delivery	Nigeria
	28	17:15	Elbar Djenette1, Rekis Abdelkrime1, Elbar Chaima Yasmin2	Transformation of Common Dates of Low Market Value into Crystallized Sugar by Freeze-Drying Process.	Algeria

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
1. Oturum	1	09:00	Mobassir Bin Anwar1, Md Shahjahan*1	Growth and Feed Utilization Responses of Nile Tilapia (Oreochromis niloticus) to Microplastics and Sumithion Co-Exposure	Bangladesh
	2	09:15	Sarower Mahfuj1,*, Sk. Mohibulla Islam1, Mst.Sabrin Akter1	Evaluating Biometric Indices and Life-History Traits of Climbing Perch, Anabas testudineus of Baluhor Oxbow Lake in Southwestern Bangladesh: Implication for Sound Management	Bangladesh
	3	09:30	Mahbuba Sultana1 and Md. Tabedar Rosul Noyon2	Behavioral Pattern and Welfare Status of Indigenous Chicken in Rural Areas of Bangladesh	Bangladesh
	4	09:45	Veli Vural Uslu,, Ramazan Beyaz	Gene Deletions and Silencing via High Pressure Spraying Technique	Bangladesh
	5	10:00	Md. Tabedar Rosul Noyon	Enhancing Egg Production Efficiency in Small-Scale Open Shed Layer Farms: A Smart Data Monitoring Case Study with 950 Birds	Yabancı
	6	10:15	Vincent Ngetich	Investigation of Factors Influencing Solubility of Whey Protein Hydrolysate-Skim Milk Powder Mixtures	Kenya
	7	10:30	Md. Mobarak Hossen	Molecular characterization of brackish and marine water fishes of Sundarbans through DNA barcodes	Yabancı

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
2. Oturum	8	11:15	Rubayet Noman, Shahana Yeasmin	Adoption of Good Agricultural Practices (GAP) by Vegetable Farmers for Safe Food: An Empirical Study on Dinajpur District	Bangladesh
	9	11:30	Mohamadou Moussa	Using compost and compost tea as biofertilizers to improve onion growth and yield in the field at Gapring-Lara in the Department of Mayo Kani (Cameroon)	Yabancı
	10	11:45	Sakhraouı-Amira Sakhraoui	Antimicrobial Potential of Prickly Pear (Opuntia ficus-indica) Seed Oil and Grain Extracts	Yabancı
	11	12:00	Femi Afolayan	Heamatology and Serum Biochemistry of West African Dwarf Goats Fed Diets Containing Treated Rice Husk (RH) as a Replacement for Wheat Bran.	Yabancı
	12	12:15	Femi Afolayan	Comparative Analysis Of Growth Performance And Economic Benefits Of West African Dwarf Goat Fed With Diets Incorporation Treated Rice Husk As A Substitute For Wheat Bran.	Yabancı
	13				
	14				

Mola / Break
12:30 – 13:30

29 Nisan 2025 Salı / 29 April 2025 Tuesday
Salon 4 – Hall 4
Oral Presentation - Online
Oturum Başkanı / Moderator: Katibe Sinem Coruk

Microsoft Teams Link: TURJAF 2025 - Online - Salon 4 / Hall 4 | Genel | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
3. Oturum	15	13:30	Hatice Filiz Boyacı	Gıda Güvenliğini Destekleme ve Sürdürülebilir Tarımı Teşvik Etmede Yabani Yenilebilir Sebzelerin Potansiyel Rolü: Doğu Karadeniz Bölgesi Örneği	Türkiye
	16	13:45	Beyhan Taş, Şeyma Palit	Farklı Işık Spektrumları Köksüz Su Mercimeğinin (Wolffia arrhiza) Morfolojik Yapısını Etkiler	Türkiye
	17	14:00	Srishti Chauhan, Prodipto Bishnu Angon	Impact of Climate Change on Harmful Crop Insects Population	Hungary
	18	14:15	Ecem Akan, Adem Yavaş	Paraprobiyotiklerin Kısa Zincirli Yağ Asitleri Üretimindeki Rolü: Mikrobiyal Etkileşimler ve Potansiyel Mekanizmalar	Türkiye
	19	14:30	Inibehe George Ukpong and Eduma E. Essien	Algorıthms And Analytıcs: An Advantage For Data-Drıven Decısıon-Makıng In Global Marketıng And Trade	Nigeria
	20	14:45	Ikenna Charles Ukwuaba, Ileka Chikaosolu MaryQueen and Umeonuorah Tochukwu Georgina	Assessing the Economic Performance of Catfish Farming in Nsukka and Enugu Metropolis, Nigeria: A Comparative Perspective	Nigeria
	21	15:00	Abdulhamid Muhammad Garba*, Sema Yaman Fırıncıoğlu	The Economic and Practical Considerations of Encapsulation in Ruminant Nutrition	Nigeria

Mola / Break
15:15 – 15:45

29 Nisan 2025 Salı / 29 April 2025 Tuesday
Salon 4 – Hall 4
Oral Presentation - Online
Oturum Başkanı / Moderator: Katibe Sinem Coruk

Microsoft Teams Link: TURJAF 2025 - Online - Salon 4 / Hall 4 | Genel | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
4. Oturum	22	15:45	Keiba dar1,3, Dassidi Lucien2, Issa Dagal Arsene3 , Abdel Hadi Mahamat Issa3	Determınatıon Of The Best Value Of Organıc And Inorganıc Mınerals To Improve Roughages Values As Anımal Feed.	Nigeria
	23	16:00	*Okoyeuzu, C. F1., Nduka, O. C1., Ugwu, I. R.1 and Nwachukwu, O. M. A1.	Productıon And Qualıty Evaluatıon Of Marmalade From Orange Fruıts Sweetened Wıth Honey	Nigeria
	24	16:15	Olakunle A. Akinsanoye, Mopelola A. Omotoso and Olugbenga A. Falode	Industrial Precursors from Agricultural Wastes	Nigeria
	25	16:30	Nchedochukwu C. Ikegbunam1*, Okwong J. Walter2, Emeka E. Osayı3, Chıedozıe A, Anukwuorjı1	Assessıng The Physıcochemıcal Compositıon And Wıde Dıversıty Of Pollen In Honey Samples Procured From Some Markets In Umudım Local Government Area Of Anambra State	Nigeria
	26	16:45	Ifedi, E. N., 1Ajayi, I. A., Olaifa, F. E. and Akintade, O. O.	Chemical and nutritional assessments of Balanite aegyptiaca seed cake used as additives in diets for Clarias gariepinus post juveniles (catfish).	Nigeria
	27	17:00	*Ahmad Alhassan1, Ahmad Usman Shu'aib1, Umar Shehu Umar1, Farouk Shehu Abdulwahab1 and Buhari Nazifi2.	Evaluation of Profitability and Cost-effectiveness of Rice Seeds Production among the Beneficiaries of KSADP/SAA in Kano State, Nigeria.	Nigeria

29 Nisan 2025 Salı / 29 April 2025 Tuesday
Salon 5 – Hall 5
Oral Presentation - Online
Oturum Başkanı / Moderator: Mutlu Bulut

Microsoft Teams Link: TURJAF 2025 - Online - Salon 5 / Hall 5 | Genel | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
1. Oturum	1	09:00	Ümmü Özgül Karagüzel	Waterlogging Stress in Ornamental Plants, Effects, Tolerance Mechanisms: A rewiew	Türkiye
	2	09:15	Yekta Gezginç, Mehmet Sakar, Betul Aylat	Biyobozunur Ambalajların Gıdalarda Kullanımı	Türkiye
	3	09:30	Hacer Tüfekci, Murat Çelebi	Practices to Reduce Offspring Mortality in Sheep and Goat Husbandry	Türkiye
	4	09:45	Nura Seyid Bekir, Sedat Sayar	Production of Pregelatized Legume Flour From Sortex Rejected Chickpea and White Kidney Bean	Türkiye
	5	10:00	Maliha Afreen*, M. Cüneyt Bağdatlı	The Negative Impacts of Migration on Agricultural Production	Pakistan
	6	10:15	İlkay Yavaş, Hayrettin İlker Özdemir, Sıdıka Ekren	Lemna minor L. (Duckweed) Importance and Usages	Türkiye
	7	10:30	BOŞLUK		

Mola / Break
10:45 – 11:15

29 Nisan 2025 Salı / 29 April 2025 Tuesday
Salon 5 – Hall 5
Oral Presentation - Online
Oturum Başkanı / Moderator: Mutlu Bulut

Microsoft Teams Link: TURJAF 2025 - Online - Salon 5 / Hall 5 | Genel | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
2. Oturum	8	11:15	Serpil Demirci Kayiran, Saliha Kırıcı, Elif Ferahoglu	Determination of the chemical composition of essential oil obtained from Cymbopogon citratus (DC.) Stapf leaves grown in Turkiye	Türkiye
	9	11:30	Ş.Sancak, A.Şimşek, G.Bakan	Sediman Ortamından Mikroplastik Gideriminde Elektrokoagülasyon Uygulamaları	Türkiye
	10	11:45	İlkay Yavaş, Hayrettin İlker Özdemir1, Sıdıka Ekren	Phytogenic Feed Additives: Their Role in Animal Nutrition	Türkiye
	11	12:00	Sevinç Kıran, Zeynep Demir, H. Filiz Boyacı, Köksal Aydınşakir, Şebnem Kuşvuran, Sinan Zengin, Ş. Şebnem Ellialtıoğlu	Combined Effects of Grafting and Vermicompost on Nutrient Composition in Eggplant under Drought Stress and Its Correlation with Yield	Türkiye
	12	12:15	Ayşe Avcı, Fikriye Alev Akçay, Elif Sezer, İnci Cerit, Esma Alemdar1, Azra Amasyalı, İbrahim Çakır	Colorimetric Detection of Biogenic Amine Formation by Various Bacillus Strains Isolated from Tarhana	Türkiye
	13				
	14				

Mola / Break
12:30 – 13:30

29 Nisan 2025 Salı / 29 April 2025 Tuesday
Salon 5 – Hall 5
Oral Presentation - Online
Oturum Başkanı / Moderator: Mutlu Bulut

Microsoft Teams Link: TURJAF 2025 - Online - Salon 5 / Hall 5 | Genel | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
3. Oturum	15	13:30	Ayşe Avcı, Elif Sezer, İnci Cerit, Esma Alemdar, Fikriye Alev Akçay, İbrahim Çakır	Isolation and Identification of Bacillus Strains from Various Tarhana Samples	Türkiye
	16	13:45	Elif Yaver	Impact of Defatted Sesame Meal on the Technological and Sensory Quality and Antioxidant Activity of Gluten-free Buckwheat Crackers	Türkiye
	17	14:00	Elife Büyüköztürk	Evaluation of the Reuse of Historical Buildings: The Case of Osmaniye Salih Sefa Yazar Folklore House	Türkiye
	18	14:15	Yusuf Şen	Fisheries and Reproductive Biology of European pilchard (Sardina pilchardus (Walbaum, 1792)) in the Southwest of Marmara Sea	Türkiye
	19	14:30	Seyit Uguz	Microalgae as a Feed Source: Market Opportunities and Challenges for Future	Türkiye
	20	14:45	Leyla İdikut*, Elif Evcimen	Farklı Azot Dozların Ekmeklik Buğdaya Çeşitlerinin Kalite Kriterlerine Etkileri	Türkiye
	21	15:00	Leyla İdikut*, Enes Hakan Seçilmiş	Mısır Bitkisinde Yaprak Uzaklaştırmanın Koçan Özelliklerine Etkisi	Türkiye

Mola / Break
15:15 – 15:45

29 Nisan 2025 Salı / 29 April 2025 Tuesday
Salon 5 – Hall 5
Oral Presentation - Online
Oturum Başkanı / Moderator: Mutlu Bulut

Microsoft Teams Link: TURJAF 2025 - Online - Salon 5 / Hall 5 | Genel | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
4. Oturum	22	15:45	Rowida Khalıly *, İlknur Ucak	The Importance of Eco-Friendly Materials in the Food Industry	Türkiye
	23	16:00	Fatma Kayaçetin1	The crude oil percentage and fatty acid profile of turnip rape in continental climate conditions	Türkiye
	24	16:15	Fatma Ergün, Demirel Ergün	The Antioxidant Activity of C. tournefortii Fruits and Leaves	Türkiye
	25	16:30	Kazım Emre Göktaş*, Leyla İdikut	Bezelye (Pisum sativum L.) Çeşitlerinin Kalite Kriterlerine Ekim Zamanlarının Etkisi	Türkiye
	26	16:45	Cem Tokatlı	Spatiotemporal Dynamics of Li, Mn, Ni, and Ba Concentrations in Sediments of Lotic Habitats in the Biga Peninsula, Türkiye	Türkiye
	27	17:00	Gökçe Eminoğlu	Çökelek Peyniri Üretiminde Farklı Starter Kültür Kullanımı	Türkiye

30 Nisan 2025 Çarşamba / 30 April 2025 Wednesday
Salon 1 – Hall 1
Oral Presentation - Online
Oturum Başkanı / Moderator: Furkan Baş

Microsoft Teams Link: TURJAF 2025 - Online - Salon 1 / Hall 1 | General | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
1. Oturum	1	09:00	Cem Tokatlı	Spatiotemporal Dynamics of Li, Mn, Ni, and Ba Concentrations in Sediments of Lotic Habitats in the Gelibolu Peninsula, Türkiye	Türkiye
	2	09:15	*Hasan Tangüler, Muhammet Çağrı Kılıç, Ayşenur İnce,	The effect of the addition of shalgam beverage residual product setik on the physical properties of tarhana	Türkiye
	3	09:30	,*Hasan Tangüler, Ayşenur İnce, Muhammet Çağrı Kılıç	Utilisation of shalgam juice residue carrot powder in yoghurt production	Türkiye
	4	09:45	Mehmet Cilbiz, Tuncay Ateşşahin2*	Seasonal and sexual variation in the length–weight relationship of narrow–clawed (Pontastacus leptodactylus Eschscholtz, 1823) crayfish in Eğirdir Lake	Türkiye
	5	10:00	Elif Meltem İşçimen	Recent trends developed to modify plant proteins, their effects and applications	Türkiye
	6	10:15	Tuğba Gözde Kendirli, Emre Yavuzer	Balık ve Yoğurt Tüketiminin Zehirlenme Algısı Açısından Biyojen Aminler Üzerinden Değerlendirilmesi	Türkiye
	7	10:30	Burak Göroğlu, Fatma Korkmaz*	Ultrasound-assisted Enzymatic Hydrolysis of Safflower Protein Isolate	Türkiye

Mola / Break
10:45 – 11:15

30 Nisan 2025 Çarşamba / 30 April 2025 Wednesday
Salon 1 – Hall 1
Oral Presentation - Online
Oturum Başkanı / Moderator: Furkan Baş

Microsoft Teams Link: TURJAF 2025 - Online - Salon 1 / Hall 1 | General | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
2. Oturum	8	11:15	Feride Özer, Kübra Ergan, Hilal Demirkesen Bıçak	Okul Çağı Çocuklarında Ambalajlı Gıda Tüketim Alışkanlıklarının Belirlenmesi Obezite İle İlişkisinin İncelenmesi	Türkiye
	9	11:30	Fatma Kayaçetin	The some quality traits of oriental mustard lines in Ankara conditions	Türkiye
	10	11:45	Abdullah Güller, Işıl Saraç Sivrikaya* ,Bekir Tosun	Evaluation of the Inhibitory Effect of Heracleum platytaenium Boiss Essential Oil Against Alternaria alternata	Türkiye
	11	12:00	Işıl Saraç Sivrikaya *, Abdullah Güller, Bekir Tosun	Can H. platytaenium Essential Oil Be Used as a Biopesticide Against White Mold Disease?	Türkiye
	12	12:15	Eda Sönmez Gürer,*, Melek Demirel, Rengin Baydar, Ayşe Esra Karadağ	In Vitro Tyrosinase and Collagenase Inhibitory Potential of Consolida orientalis from Türkiye	Türkiye
	13				
	14				

Mola / Break
12:30 – 13:30

30 Nisan 2025 Çarşamba / 30 April 2025 Wednesday
Salon 1 – Hall 1
Oral Presentation - Online
Oturum Başkanı / Moderator: Ali Kaan Yetik

Microsoft Teams Link: TURJAF 2025 - Online - Salon 1 / Hall 1 | General | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
3. Oturum	15	13:30	Kemal Eskioğlu, Demir Özdemir	Disease Prediction in Poultry Using Artificial Intelligence Tools	Türkiye
	16	13:45	Elif Sezer, Goncagül Balcı, İleyda Demirbaş, Şevval Dülger, Ayşen Can	Probiotic and Paraprobiotic Fermented Milk Enriched with Jujube and Pumpkin Fruits	Türkiye
	17	14:00	Meliha Polen Artun, Saliha Kırıcı	Determination of yield and quality characteristics of Patchouli (Pogostemon cablin) plant in Çukurova conditions	Türkiye
	18	14:15	Osman İnanç Güney	The Impact of Socio-Demographic Characteristics of Consumers on Food Preferences: The Case of Türkiye	Türkiye
	19	14:30	Osman İnanç Güney	The Community Supported Agriculture Model: An Approach Based on Local Food Production and Solidarity	Türkiye
	20	14:45	Tuğçe Yüleci Kurtcu, Mukaddes Kılıç Bayraktar	Effects of Pseudocereals and Germination on Gut Microbiota	Türkiye
	21	15:00	Yeşim Sıla Tekin*, Hande Eser, Seda Kaçar, Büşra Görgülü, Serkan Benli, Hasan Hüseyin Mutlu	Applications of Mycorrhiza in Plant Development	Türkiye

Mola / Break
15:15 – 15:45

30 Nisan 2025 Çarşamba / 30 April 2025 Wednesday
Salon 1 – Hall 1
Oral Presentation - Online
Oturum Başkanı / Moderator: Ali Kaan Yetik

Microsoft Teams Link: TURJAF 2025 - Online - Salon 1 / Hall 1 | General | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
4. Oturum	22	15:45	Önay Altunal, Sedat Sayar	Determination of Quality Characteristics of Cracked Wheat (Dövme) Obtained From Different Wheat Verieties	Türkiye
	23	16:00	Özden Salman, Raziye Koçak	Antagonistic Activity of Endophytic Fungi from Euphorbia rigida against Botrytis cinerea in Tomato	Türkiye
	24	16:15	Maliha Afreen*, İlknur Uçak, M. Cüneyt Bağdatlı	Innovative Trends in Food Production of Europe	Pakistan
	25	16:30	Sema Ezgi Yüceer, Sibel Tan	Karbon Emisyonlarının Tarım Sektörü Üzerine Etkileri: Türkiye-AB Karşılaştırması	Türkiye
	26	16:45	Semih Bahadır Ecemiş, Emre Yavuzer, Memduh Köse	Farklı Şekillerde Dondurulduktan Sonra Termal Strese Maruz Bırakılan Alabalıkların Kalite Değişimlerinin Makine Öğrenmesi İle Belirlenmesi	Türkiye
	27	17:00	Meral Kekeçoğlu *Münir Uçak, Songül Bir	The Current Situation And Future of Beekeeping in Düzce	Türkiye

30 Nisan 2025 Çarşamba / 30 April 2025 Wednesday
Salon 2 – Hall 2
Oral Presentation - Online
Oturum Başkanı / Moderator: Beyazıt Abdurrahman Şanlı

Microsoft Teams Link: TURJAF 2025 - Online - Salon 2 / Hall 2 | General | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
1. Oturum	1	09:00	Sevde Nur Çataltepe, Nurhan Uslu , Mehmet Musa Özcan	Comparison of Bioactive Properties and Phenolic Compounds of Turkish Coffee, Filter Coffee and Espresso Coffee	Türkiye
	2	09:15	Zeki Bayramoğlu, Hasan Gökhan Doğan, Serhan Candemir3	The Effect of Macroeconomic Variables on Agricultural Production in Türkiye	Türkiye
	3	09:30	Zeki Bayramoğlu, Serhan Candemir, Hasan Gökhan Doğan	The Effects of the Russia-Ukraine War on Foreign Dependency and Fragility in Sunflower Production in Türkiye	Türkiye
	4	09:45	Fikrîye Alev Akçay, Ayşe Avcı	Evaluation of Bacillus Strains for Protease Production	Türkiye
	5	10:00	Mustafa Guzel	Tracking Salmonella in Sesame Foods: Genomic Diversity and Resistance Patterns	Türkiye
	6	10:15	Melih Aydınlı1	Responses of Some Almond (Prunus dulcis) Varieties to Drought Stress	Türkiye
	7	10:30	Dilek Savaşlı Yıldırım, Elif Ferahoğlu, Saliha Kırıcı	Determination of Yield and Quality Characteristics of Immortal Flower (Helichyrsum italicum (Roth) G. Don fil.) Plant Conditions at Different Growth Periods in Çukurova Conditions	Türkiye

Mola / Break
10:45 – 11:15

30 Nisan 2025 Çarşamba / 30 April 2025 Wednesday
Salon 2 – Hall 2
Oral Presentation - Online
Oturum Başkanı / Moderator: Beyazıt Abdurrahman Şanlı

Microsoft Teams Link: TURJAF 2025 - Online - Salon 2 / Hall 2 | General | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
2. Oturum	8	11:15	Arzu Üçtepe	Feather-Plucking in Blue-Breasted Quails (Synoicus chinensis): An Abnormal Behavior Associated with Courtship Feeding?	Türkiye
	9	11:30	Ahmet Bayrac, Ali Kahraman*, Onur Okumus, Neslihan Doruk Kahraman	Economics of Agriculture and Sustainability of Agro-Economy	Türkiye
	10	11:45	Ali Kahraman*, Onur Okumus, Neslihan Doruk Kahraman	Sinkholes and Agricultural Sustainability	Türkiye
	11	12:00	Ahmet Akay, Gözdenur Yılmaz	Yenilebilir Peyzaj Bahçelerinin Üniversite Öğrencileri Üzerindeki Etkileri: Selçuk Üniversitesi Örneği	Türkiye
	12	12:15	Ahmet Akay, Gözdenur Yılmaz	Alışveriş Merkezi Otoparklarında Gölge Ağaçlarının İncelenmesi ve Peyzaj Tasarım Önerisi: Konya M1 AVM Örneği	Türkiye
	13				
	14				

Mola / Break
12:30 – 13:30

30 Nisan 2025 Çarşamba / 30 April 2025 Wednesday
Salon 2 – Hall 2
Oral Presentation - Online
Oturum Başkanı / Moderator: Orkun Gencer

Microsoft Teams Link: TURJAF 2025 - Online - Salon 2 / Hall 2 | General | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
3. Oturum	15	13:30	Gülden Sandal Erzurumlu	The Use of Capsule Houses in Landscape Design Studies	Türkiye
	16	13:45	Nurdan Topakcı	Biyolojik Mücadele Uygulanan Biber Seralarında Farklı Tonlardaki Sarı ve Mavi Yapışkan Tuzaklarda Orius laevigatus ve Creontiades Pallidus'un Yakalanma Durumunun Belirlenmesi	Türkiye
	17	14:00	Gülden Sandal Erzurumlu, Umut Poyraz	The Use Of Installation Art In Landscape Desıgns Of Urban Areas	Türkiye
	18	14:15	Wadah Elsheikh*, M. Cüneyt Bağdatlı	Accessing Drinking Water and Global Warming in Sudan	Sudan
	19	14:30	Neslihan Doruk Kahraman, Onur Okumus, Ali Kahraman*	Sustainable Agriculture: Soil and Cover Crops	Türkiye
	20	14:45	Neslihan Doruk Kahraman*, Onur Okumus, Ali Kahraman	Seed Coating and Sustainable Agriculture	Türkiye
	21	15:00	Müberra Birkan, Hatice Bekiroğlu, Görkem Özülkü	Enrichmet of cakes with elderberry extract : Effects of different formulations on bioactive properties and cake quality	Türkiye
Mola / Break 15:15 – 15:45					

30 Nisan 2025 Çarşamba / 30 April 2025 Wednesday
Salon 2 – Hall 2
Oral Presentation - Online
Oturum Başkanı / Moderator: Orkun Gencer

Microsoft Teams Link: TURJAF 2025 - Online - Salon 2 / Hall 2 | General | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
4. Oturum	22	15:45	Rana Özdemir, Münir Uçak	Scanning Electron Microscopy (SEM) Techniques on Honey Bee Taxonomic Studies	Türkiye
	23	16:00	Hakan Borucuoğlu, Cüneyt Suzer, Onurkan Antepli, İbrahim Köse, Müge Hekimoğlu, Şahin Saka, Kürşat Fırat	Effect of Glycyrrhizic Acid on Growth Performance in Meagre (Argyrosomus regius) Juveniles	Türkiye
	24	16:15	Özge Aksu, Cüneyt Suzer, Onurkan Antepli1, İbrahim Köse1, Kürşat Fırat, Şahin Saka	Reduction of Live Feed in the Early Life of Sea Bream (Sparus aurata, L.) Larviculture: Effects on Enzymatic and Histomorphological Development	Türkiye
	25	16:30	Ebru Köroğlu1, Berkay Berk1, Sevcan Ünlütürk1	Effect of Needle Micro-Perforation Pretreatment as an Alternative to Alkaline Dipping Solution in Grape Drying on Bioactive Compounds	Türkiye
	26	16:45	Nebi Seren	Tarımda Dijital Teknolojilerin Kullanımı: Üretim ve Pazarlama Açısından Karşılaştırmalı Analiz	Türkiye
	27	17:00	Hatice Sena Olcay1,2	Effect of Orange Albedo on Nutritional, Functional and Cooking Properties of Semolina Pasta	Türkiye

30 Nisan 2025 Çarşamba / 30 April 2025 Wednesday
Salon 3 – Hall 3
Oral Presentation - Online
Oturum Başkanı / Moderator: Musa Sürücü

Microsoft Teams Link: TURJAF 2025 - Online - Salon 3 / Hall 3 | Genel | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
1. Oturum	1	09:00	İlayda Özçelik*, Ayşenur Acar and Nihat Akın	Determination of the Usability of Permeate and Strained Yoghurt Water Separated as Dairy by-product in the Production of a Shalgam-like Product	Türkiye
	2	09:15	Hümeyra Duymaz, Berna Öztürk	A Traditional Fermented Food: Miso	Türkiye
	3	09:30	Ali Akçaova	Professional Practice Knowledge in Interior Architecture Education, Exploration, Quantity Surveying and Approximate Cost	Türkiye
	4	09:45	Furkan Aksoy	Recent Applications in Computer Vision-based Lameness Detection of Dairy Cattles	Türkiye
	5	10:00	Ali Akçaova	The Role of Biomimicry in Interior Architecture Education and Structural Forms	Türkiye
	6	10:15	Murat Seyhan, Sertaç Güngör	Comparative Analysis of Tropical Butterfly Garden and Kalehan Ecdat Park in Konya Selçuklu District in Terms of User Preferences	Türkiye
	7	10:30	Hatice Ballan, Sertaç Güngör	Safety Factor in Children's Playground Design: A Research in the Case of Seydişehir National Garden	Türkiye

Mola / Break
10:45 – 11:15

30 Nisan 2025 Çarşamba / 30 April 2025 Wednesday
Salon 3 – Hall 3
Oral Presentation - Online
Oturum Başkanı / Moderator: Musa Sürücü

Microsoft Teams Link: TURJAF 2025 - Online - Salon 3 / Hall 3 | Genel | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
2. Oturum	8	11:15	Fatma Nur Yılmaz, Zeki Bayramoğlu	Value Added Analysis of Grape Production in Dulkadiroğlu District of Kahramanmaraş Province	Türkiye
	9	11:30	Duried Alwazeer, Berrak Iğdır	Hydrogen Farmıng	Türkiye
	10	11:45	Duried Alwazeer, Şafak Yılmaz	Fenolik bileşikler ile mineraller arasındaki etkileşim mekanizmaları ve besinsel etkileri	Türkiye
	11	12:00	Münüre Tanur Erkoyuncu	Effects of GA_3 and PLGA-Controlled Release of GA_3 on the Germination of Caraway (Carum carvi L.)	Türkiye
	12	12:15	Ceylin Özcan, Cüneyt Suzer, Onurkan Antepli, İbrahim Köse, Kürşat Fırat, Şahin Saka	Using of Probiotics and Growth Promoters in Sea Bream (Sparus aurata, L.) Larval Culture: Combined Effects on Growth Performance and Morphological Development	Türkiye
	13				
	14				

Mola / Break
12:30 – 13:30

30 Nisan 2025 Çarşamba / 30 April 2025 Wednesday
Salon 3 – Hall 3
Oral Presentation - Online
Oturum Başkanı / Moderator: Betül Oskaybaş Emlek

Microsoft Teams Link: TURJAF 2025 - Online - Salon 3 / Hall 3 | Genel | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
3. Oturum	15	13:30	Raziye Koçak, Özden Salman, Bahadır Şin	Evaluation of the Antifungal Effects of Datura stramonium Extracts on Sclerotinia sclerotiorum and Rhizoctonia solani under In Vitro Conditions	Türkiye
	16	13:45	Muhammad Sameeullah	Comparative Aluminum Stress Tolerance in Red (Fırat-87) and Black-Seeded (Beluga) Lentils	Türkiye
	17	14:00	Elif Şahin Suci, Nuh Uğurlu	A Comprehensive Study on Heat Balance Analyses in Grain Warehouses During the Winter Season: The Case of Konya Province	Türkiye
	18	14:15	Basri Omac	Comparison of Secondary Models for Modeling the Growth of Salmonella in Leafy Greens	Türkiye
	19	14:30	Nuran Gökçen Aslan, Zülal Tezcan, Sudenaz Kızıldağ, Nalan Yazıcıoğlu	Optımızatıon of ultrasonıc assısted extractıon of bıoactıve compounds of rumex acetosella	Türkiye
	20	14:45	Mehmet Akif Kalender, Ramazan Topak	Evaluation of Individual Groundwater (GW) Irrigation in the Konya Closed Basin in Terms of Energy Consumption and Greenhouse Gas Emissions	Türkiye
	21	15:00	Emrah Güngör	The Effect of Solid-State Fermentation using Aspergillus niger on the Nutritional Composition of Grape Seed, Cherry Kernel, and Maize Seed Mixture	Türkiye

Mola / Break
15:15 – 15:45

30 Nisan 2025 Çarşamba / 30 April 2025 Wednesday
Salon 3 – Hall 3
Oral Presentation - Online
Oturum Başkanı / Moderator: Betül Oskaybaş Emlek

Microsoft Teams Link: TURJAF 2025 - Online - Salon 3 / Hall 3 | Genel | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
4. Oturum	22	15:45	Oğuz Ateş, Engin Kabataş, Fürüzan Çelik	İklim ve Arazi Örtüsü Değişikliği Bağlamında Havza Ölçeğinde Gelecekteki Toprak Erozyonun Tahmini	Türkiye
	23	16:00	İsmail Yaşhan Buluş*, Mustafa Güneşdoğdu	Arıcılarda Egzama: Nedenleri ve Risk Faktörleri	Türkiye
	24	16:15	Wadah Elsheikh*, İlknur Uçak, M. Cüneyt Bağdatlı	Developments of Food Industry 4.0 in Europe	Sudan
	25	16:30	Bahadır Şin, Raziye Koçak, Özden Salman	Antifungal Activity of Methanol Extracts Obtained from Verbascum L. (Mullein) Species Collected from Different Regions Against Rhizoctonia solani	Türkiye
	26	16:45	İsmail Yaşhan Buluş, Mustafa Güneşdoğdu	Biyopestisitlerin Arılar Üzerindeki Olumsuz Etkileri	Türkiye
	27	17:00	Hülya Hanoğlu Oral	Evaluation of the Relationship Between Condensed Tannin Content and Rumen Protein Degradability in Sainfoin (Onobrychis viciifolia)	Türkiye

30 Nisan 2025 Çarşamba / 30 April 2025 Wednesday
Salon 4 – Hall 4
Oral Presentation - Online
Oturum Başkanı / Moderator: Betül Demir

Microsoft Teams Link: TURJAF 2025 - Online - Salon 4 / Hall 4 | Genel | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
1. Oturum	1	09:00	Hatice Kubra Sasmaz, Turkan Uzlasır, Pınar Kadıroglu, Hasim Kelebek*	Comparison of Composition and Bioactive Properties of Garlic from Gaziantep and Kahramanmaraş	Türkiye
	2	09:15	Khawar Jabran	Seed scarification relieves weed seed dormancy in Convolvulus arvensis	Türkiye
	3	09:30	Turkan Uzlasır*, Hatice Kübra Şaşmaz, Hasim Kelebek	Effect of infusion time on the biochemical composition of Tamarindus indica	Türkiye
	4	09:45	Gülsüm Manav, Kemal Eskioğlu, Demir Özdemir	Mapping the Genetic Structure in Chicken Genomes Using SNP Chips: Perspectives on Conservation and Breeding	Türkiye
	5	10:00	Hatice Kübra Şaşmaz, Hasim Kelebek*	Aged Garlic Extract: Bioactive Components and Functional Properties	Türkiye
	6	10:15	K. Gerbaga Özsemir, D. Sezer	Oviductal Impaction in Three Budgerigars (Melopsittacus undulatus): A Case Report and Systematic Review	Türkiye
	7	10:30	Gülsüm Manav, Demir Özdemir	Native Chicken of the Black Sea Region: Trabzon Gugullisi	Türkiye

Mola / Break
10:45 – 11:15

30 Nisan 2025 Çarşamba / 30 April 2025 Wednesday
Salon 4 – Hall 4
Oral Presentation - Online
Oturum Başkanı / Moderator: Betül Demir

Microsoft Teams Link: TURJAF 2025 - Online - Salon 4 / Hall 4 | Genel | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
2. Oturum	8	11:15	Furkan Ozan Çöven, Tülay Öncü-Öner*	Bioactivities of Thymbra spicata: Exploring its Cytotoxic, Antibacterial and Antiviral Activities	Türkiye
	9	11:30	İbrahim Cihangir Okuyucu	Effects of milking methods on test-day milk yield and milk quality traits in early lactating multiparous buffalo cows and the relationships among these parameters	Türkiye
	10	11:45	Ebru Akgül, Tülin Eker, Haşim Kelebek, Pınar Kadiroglu	Cloud Point Extraction for the Recovery of Bioactive Compounds from Peanut Shells	Türkiye
	11	12:00			
	12	12:15	Fatma Yenice, Zeynep Akşit	Phenolic Compounds Found in Citrus Species	Türkiye
	13		Zeynep Günyel, Zeynep Akşit	Sausage and Shelf Life Studies	Türkiye
	14				

Mola / Break
12:30 – 13:30

30 Nisan 2025 Çarşamba / 30 April 2025 Wednesday
Salon 4 – Hall 4
Oral Presentation - Online
Oturum Başkanı / Moderator: Betül Demir

Microsoft Teams Link: TURJAF 2025 - Online - Salon 4 / Hall 4 | Genel | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
3. Oturum	15	13:30	Can Mavruk, Aziz.Cumhur Kocalar	Nutrient Balance and Efficiency in Agricultural Activities from Nutrients and Cereals	Türkiye
	16	13:45	Aysel Kekillioğlu, Ömer Eren Bostan	Bioecological and Faunistic Investigation of Insect Taxa in Patato Agricultural Areas and Surroundings of Derinkuyu District	Türkiye
	17	14:00	Zekerya Bıçak, Aysel Kekillioğlu, Feride Nur Öztürk	Evaluation of Cytotoxic Effect of Selenium Nanoparticles (An-SeNP) Obtained by Green Synthesis Method with *Inula viscosa* L. Extract on Hep-G2 Liver Cancer Cells	Türkiye
	18	14:15	Emre Hastaoğlu	Food Waste Prevention Training: Content Determination	Türkiye
	19	14:30	Emre Hastaoğlu	Turkey's Map of Aromatic Plants and Spices	Türkiye
	20	14:45	Tuba Bak, Levent Kırca	Morphological Characteristics of Apple Genotypes in Mudurnu-Bolu	Türkiye
	21	15:00	Derya Demiralan, Eminur Elçi	Biological Characterization of Tomato brown rugose fruit virus-Antalya Isolates	Türkiye

Mola / Break
15:15 – 15:45

30 Nisan 2025 Çarşamba / 30 April 2025 Wednesday
Salon 4 – Hall 4
Oral Presentation - Online
Oturum Başkanı / Moderator: Betül Demir

Microsoft Teams Link: TURJAF 2025 - Online - Salon 4 / Hall 4 | Genel | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
4. Oturum	22	15:45	Ali Enes Özdemir, Eminur Elçi	Molecular Characterization of Tomato brown rugose fruit virus-Isparta Isolates Movement Protein	Türkiye
	23	16:00	İrem Kılınç*, Çiğdem Takma, Berna Kılınç, Yakut Gevrekçi	Sustainability and Environmental Footprints of AI-Integrated Agrifood Production Systems	Türkiye
	24	16:15	Lerzan Öztürk*, Nur Sivri	Feeding and reproduction of Aphelenchus avenae, Aphelenchoides sacchari and Aphelenchoides clarus on cultures of soil related fungi Aspergillus niger, A. flavus, and Fusarium oxysporum	Türkiye
	25	16:30	Özlem Üstün-Aytekin*, Rüya Kuru-Yaşar, Şahin Yılmaz2, Fikrettin Şahin	Nutritional and Health Implications of Some Essential and Non-Essential Elements in Edible Salts Commonly Consumed in Türkiye	Türkiye
	26	16:45	Ibrahim Isse Ali Hafsah Mahmoud Akraym, Kubilay Kurtulus Bastas*	Comparative Study of Biological Control Agents against Common Bacterial Blight Disease in Dry Beans	Türkiye
	27	17:00	Sukriye Melis Ozsarac1, Kubilay Kurtulus Bastas,*	Insights into the Apple Tree Microbiome: Determination of Pathogenic and Beneficial Bacteria	Türkiye

30 Nisan 2025 Çarşamba / 30 April 2025 Wednesday
Salon 5 – Hall 5
Oral Presentation - Online
Oturum Başkanı / Moderator: Özlem Boran

Microsoft Teams Link: TURJAF 2025 - Online - Salon 5 / Hall 5 | Genel | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
1. Oturum	1	09:00	Md. Masudul Haque, Anirban Sarker, Shilpi Saha, Akond Mohammad Rafiqul Islam, Mohammad Abdul Baki*	Effect of stocking density on crablets nursing performance and assessment of growth comparison between wild-sourced and hatchery-sourced juvenile crabs	Bangladesh
	2	09:15	B Karmakar1*, A Henry2, SM Haefele4, MHR Mukul3, MM Hasan3, A. Kumar4	Field Screening of Rice Genotypes in Drought-prone Rainfed Environment	Bangladesh
	3	09:30	Muhammad Saleem Kashif1, Zahid Ata Cheema2, Muhammad Farooq3 and Hafiz Haider Ali1	Allelopathy and Agronomy: An integrated Approach for Sustainable Management of Little Seed Canary Grass (Phalaris minor Retz.) in Wheat Cropping System of Pakistan	Pakistan
	4	09:45	Çiğdem Albayrak, Serkan Yeşil	Determination of the Presence and Infection Rates of Bean common mosaic virus (BCMV), Bean yellow mosaic virus (BYMV) and Bean common mosaic necrosis virus (BCMNV) in Bean Planting Areas in Karaman Province	Türkiye
	5	10:00	Sheida Moradi	Chemical Constituents Of Propolis Relevant To Its Use In Polymeric Formulations	Cyprus
	6	10:15	BOŞLUK		
	7	10:30	BOŞLUK		

Mola / Break
10:45 – 11:15

30 Nisan 2025 Çarşamba / 30 April 2025 Wednesday
Salon 5 – Hall 5
Oral Presentation - Online
Oturum Başkanı / Moderator: Özlem Boran

Microsoft Teams Link: TURJAF 2025 - Online - Salon 5 / Hall 5 | Genel | Microsoft Teams

Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
2. Oturum	8	11:15	Yusuf Gümüş, Aysun Uysal, Merve Oğuz*, Soner Soylu, Emine Mine Soylu, Şener Kurt	Determination of in vitro Antagonistic Activity of Burkholderia ambifaria against Fungal Storage Diseases in Citrus Fruits	Türkiye
	9	11:30	Yağmur Ötün, Ahmet Regaib Oğuz	Investıgatıon of the Effects of Propolis on Some Blood Parameters in Rainbow Trout (Oncorhynchus Mykiss) Exposed to Long-Term Bısphenol-A	Türkiye
	10	11:45	Esra Kibar Balballı, Gülşah Karabulut	Extraction and Isoelectric Precipitation of Protein from Hazelnut Meal	Türkiye
	11	12:00	Rabia Yayla, Hasan Karaosmanoğlu	Fındık İşletmelerinde Gıda Güvenliği: Riskler ve Çözüm Önerileri	Türkiye
	12	12:15	Arzu Üçtepe	The Current Role of Turkey (Meleagris gallopavo) Breeding in Poultry Production: Türkiye and World Perspectives	Türkiye
	13				
	14				

Mola / Break
12:30 – 13:30

30 Nisan 2025 Çarşamba / 30 April 2025 Wednesday
Salon 5 – Hall 5
Oral Presentation - Online
Oturum Başkanı / Moderator: Özlem Boran

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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
3. Oturum	15	13:30	Neslişah Okur*, Senem Kamiloglu	Extraction of Anthocyanins from Food Waste Using Ultrasound- and Microwave-Assisted Methods	Türkiye
	16	13:45	Muhsin Yıldız*	Mikroalg Kullanımının Turpta (Raphanus sativus L.) Tohum Çimlenmesi ve Erken Dönem Bitki Gelişimi Üzerine Etkisi	Türkiye
	17	14:00	Ozlem Cakmakci, Talip Cakmakci, Suat Sensoy	Impact of foliar applied rutin on some physiological and yield parameters of lettuce under different saline irrigation water stress	Türkiye
	18	14:15	Beyhan Yeter*, Hasan Eleroğlu	Farklı Yetiştirme Sistemlerinde Barındırılan Atak-S Erkek Civcivlerinin Et Kalite Özellikleri	Türkiye
	19	14:30	Beyhan Yeter,*, Hasan Eleroğlu	Yavaş Gelişen Hubbard Red JA57 Etlik Piliçlerinin Farklı Yetiştirme Sistemlerinde Et Kalite Özellikleri	Türkiye
	20	14:45	Kurai Gareth Mawoneke, Humphrey Masimba Makumbirofa, Takudzwa Rusike	Title: Harnessing Neglected and Underutilized Crop Species in Sub-Saharan Africa: A Pathway to Food Security and Sustainable Agriculture	Zimbabwe
	21	15:00	Abdelaziz Elfazzıkı, Mohamed Yassine Samırı	Democratization of Crop Irrigation: An Intelligent Approach Combining IoT, Machine Learning, and Social and Solidarity Economy	Morocco

Mola / Break
15:15 – 15:45

30 Nisan 2025 Çarşamba / 30 April 2025 Wednesday
Salon 5 – Hall 5
Oral Presentation - Online
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Oturum Session	Sunum Presentation	Sunum Saati Presentation Time	Yazarlar Authors	Çalışma Adı Paper Name	Ülke Country
4. Oturum	22	15:45	Ulrich Sosthène Hodonou, Hasan Eleroğlu, Recep Gümüş3	The direction of broiler farming research in recent decades	Benin
	23	16:00	Ulrich Sosthène Hodonou, Gülay Demir	Bıblıometrıc analysıs of studıes on factors affectıng egg qualıty	Benin
	24	16:15	İrem Kılınç*, Çiğdem Takma, Berna Kılınç, Yakut Gevrekçi	Sustainability and Environmental Footprints of AI-Integrated Agrifood Production Systems	Türkiye
	25	16:30	Mustafa Güneşdoğdu	Determination of honeybees preference for dry protein replacement diets at different locations	Türkiye
	26	16:45	Mustafa Güneşdoğdu	Possibilities of Using Microalgae Varieties in Beekeeping Research	Türkiye
	27	17:00	Adem Savaş	Aflatoxins in hazelnuts and their effects	Türkiye
	28	17:15	Adem Savaş	Determination of Amino Acid Profile of Sea Bass Cooked in Microwave Oven	Türkiye

PREFACE

Dear Colleagues…

The " 4th International Congress of the Turkish Journal of Agriculture - Food Science and Technology (TURJAF 2025) " has been held in Niğde/Türkiye on 28-30 April, 2025, with the participation of scientists working in agriculture and related sciences, with the aim of sharing scientific developments, proposing scientific solutions to international problems, increasing cooperation and creating scientific outputs that will benefit humanity by using international resources economically.

416 papers from 45 countries were presented to our congress. 225 of these papers came from foreign countries and 191 came from Türkiye. The countries of the participants who sent papers to the congress and the number of incoming articles are as follows; Albania (2), Algeria (10), Azerbaijan (1), Bangladesh (34), Benin (2), Burkina Faso (1), Cameroon (1), China (3), Côte d'Ivoire (2), Cyrus (3), Ecuador (2), Egypt (2), England (1), Ethiopia (6), Germany (1), Ghana (5), Hungary (1), India (4), Iran (8), Iraq (3), Italy (7), Kazakhstan (4), Kenya (6), Kırgızistan (1), Kosova (1), Morocco (1), Nepal (4), Netherlands (1), Nigeria (47), Pakistan (26), Peru (1), Philippines (4), Poland (1), Roma (1), Romania (2), Saudi Arabia (2), Somalia (2), Sri Lanka (8), Sudan (6), Tanzania (2), Tunissia (3), Uganda (1), USA (1), Zimbabwe (1) and Türkiye (191). The rate of international papers is 54.08% (more than one paper by the same author was received as one; (100×225/(225+191))= 54.08%).

At the congress; participants discussed such topics as animal production, crop production, aquaculture, food science and technologies, agricultural technologies, soil science, sustainable agricultural systems, agricultural economics, genetics, biology, agricultural ecology, landscape architecture and agricultural environment issues related to original, advanced technology on agriculture and natural life.

During the organization and congress phase of the congress; Assoc. Prof. Dr. Burak ŞEN, Dr. Mustafa DUMAN, Dr. Mehmet YETİŞEN, Dr. Brian TAINIKA, Dr. Ali Kaan YETIK, Ahmet AKYOL, Furkan BAŞ, Muhammet Talha İNCE, Musa SÜRÜCÜ, Beyazıt Abdurrahman ŞANLI, Orkun GENCER, Katibe Sinem CORUK, Ayşenur İNCE took on important duties in the congress secretariat.

We would like to express our gratitude to all our stakeholders who supported the successful realization of our congress and all the scientists who participated and supported us with their papers.

4th International Congress of the Turkish Journal of Agriculture - Food Science and Technology (TURJAF 2025) was supported by TUBITAK within the scope of "2223-B - Grant Program for Organizing Scientific Meeting within the Country".

Kind regards

ÖNSÖZ

Sayın Meslektaşlarımız…

Tarım ve ilgili bilim dallarında çalışan bilim insanlarının katılımıyla, bilimsel gelişmeleri paylaştıkları, uluslararası sorunlara bilimsel çözümler önermek, iş birliklerini artırarak uluslararası
kaynakların ekonomik kullanılmasıyla insanlığın yararına olacak bilimsel çıktıların oluşturulması amacıyla, 28-30 Nisan 2025 tarihinde Niğde/Türkiye'de "4. Uluslararası Türk Tarım - Gıda Bilimi ve Teknolojileri Dergisi Kongresi (TURJAF 2025)" gerçekleştirilmiştir.

Kongremize 40 ülkeden 416 bildiri sunulmuştur. Bu bildirilerin 225'i yurt dışından, 191'si ise Türkiye'den gelmiştir. Kongreye bildiri gönderen katılımcıların ülkeleri ve gelen makale sayıları şu şekildedir; Albania (2), Algeria (10), Azerbaijan (1), Bangladesh (34), Benin (2), Burkina Faso (1), Cameroon (1), China (3), Côte d'Ivoire (2), Cyrus (3), Ecuador (2), Egypt (2), England (1), Ethiopia (6), Germany (1), Ghana (5), Hungary (1), India (4), Iran (8), Iraq (3), Italy (7), Kazakhstan (4), Kenya (6), Kırgızistan (1), Kosova (1), Morocco (1), Nepal (4), Netherlands (1), Nigeria (47), Pakistan (26), Peru (1), Philippines (4), Poland (1), Roma (1), Romania (2), Saudi Arabia (2), Somalia (2), Sri Lanka (8), Sudan (6), Tanzania (2), Tunissia (3), Uganda (1), USA (1), Zimbabwe (1) ve Türkiye (191). Yurtdışı bildiri oranı %55.26'dır (aynı yazara ait birden fazla bildiriler tek olarak alınmıştır; (100×225/(225+191))= 54.08%).

Kongrede; tarım ve doğal hayat ile ilgili özgün ve ileri teknoloji ile ilgili; hayvansal üretim, bitkisel üretim, su ürünleri, gıda bilimi ve teknolojileri, tarım teknolojileri, toprak bilimi, sürdürülebilir tarım sistemleri, tarım ekonomisi, genetik, biyoloji, tarımsal ekoloji, peyzaj mimarlığı ve tarımsal çevre konuları katılımcılar tarafından tartışılmıştır.

Kongremizin düzenlenmesi ve kongre aşamasında; kongre sekretaryasında önemli görevler üstlenen Doç. Dr. Burak ŞEN, Dr. Mustafa DUMAN, Dr. Mehmet YETİŞEN, Dr. Brian TAINIKA, Dr. Ali Kaan YETIK, Ahmet AKYOL, Furkan BAŞ, Muhammet Talha İNCE, Musa SÜRÜCÜ, Beyazıt Abdurrahman ŞANLI, Orkun GENCER, Katibe Sinem CORUK, Ayşenur İNCE kongre organizasyonunu üstlenmişlerdir.

Kongremizin başarılı bir şekilde gerçekleştirilmesinde desteklerini esirgemeyen tüm paydaşlarımıza ve bildirileri ile katılarak destek veren tüm bilim insanlarına teşekkürü bir borç biliriz.

4. Uluslararası Türk Tarım - Gıda Bilimi ve Teknolojileri Dergisi Kongresi (TURJAF 2025), TÜBİTAK tarafından "2223-B - Yurt İçi Bilimsel Etkinlik Düzenleme Desteği Programı" kapsamında desteklenmiştir.

Saygılarımızla

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Yayın Ve Düzenlemede Görevlendirilmiş Akademisyen Temsilci

28-30 Nisan 2025 tarihinde Niğde/Türkiye'de "4. Uluslararası Türk Tarım - Gıda Bilimi ve Teknolojileri Dergisi Kongresi (TURJAF 2025)" gerçekleştirilmesinde, Niğde Ömer Halisdemir Üniversitesi Rektörlüğü'nün 13/02/2025 Tarih E-87795264-903.07-621211 sayılı olurları ile aşağıda isimleri verilen akademisyenlere ***yayın ve düzenlemede akademik temsilci*** olarak yer almalarına izin verilmiştir.

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Assist. Prof. Dr.	Malik H. KAREM	College of Agriculture, AL-Muthanna University	Iraq
Assist. Prof. Dr.	Ahmed Shamhi JABBAR	University of Al-Qadisiyah	Iraq

2. Yurt dışından katılım sağlanan ülkeler ve bidiri sayıları

SN	Ülke	Bidiri sayısı
1	Albania	2
2	Algeria	10
3	Azerbaijan	1
4	Bangladesh	34
5	Benin	2
6	Burkina Faso	1
7	Cameroon	1
8	China	3
9	Côte d'Ivoire	2
10	Cyrus	3
11	Ecuador	2
12	Egypt	2
13	England	1
14	Ethiopia	6
15	Germany	1
16	Ghana	5
17	Hungary	1
18	India	4
19	Iran	8
20	Iraq	3
21	Italy	7
22	Kazakhstan	4
23	Kenya	6
24	Kırgızistan	1
25	Kosova	1
26	Morocco	1
27	Nepal	4
28	Netherlands	1
29	Nigeria	47
30	Pakistan	26
31	Peru	1
32	Philippines	4
33	Poland	1
34	Roma	1
35	Romania	2
36	Saudi Arabia	2
37	Somalia	2
38	Sri Lanka	8
39	Sudan	6
40	Tanzania	2
41	Tunissia	3
42	Türkiye	191
43	Uganda	1
44	USA	1
45	Zimbabwe	1

3. Yurt dışı katılım oranı

Ülke	Bildiri sayısı (birden fazla bildiriyle katılım)
Yurt dışı	225
Yurt içi	191
Oran	54.08

Yukarıda verilen bilgiler çerçevesinde, 28-30 Nisan 2025 tarihinde Niğde/Türkiye'de " 4. Uluslararası Türk Tarım - Gıda Bilimi ve Teknolojileri Dergisi Kongresi (TURJAF 2025) ", uluslararası kongre niteliği taşımakta, akademik teşvik kriterleri ve UAK Doçentlik başvuru koşullarını sağlamıştır.

ID: 351

Recent studies and future expectations in broiler breeding in Turkey

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Abstract

Turkey ranks in the top 10 in broiler production in the world. Almost all of the genetic material used in production in our country is provided by commercial international breeding companies. In order to reduce complete external dependency in this field and to have improved genetic stocks, broiler breeding studies have been restarted in Turkey since 2010. The studies, which started with a project (TÜBİTAK 109O334) to produce slow-growing broiler parents, have been put into practice by the Ministry of Agriculture and Forestry, General Directorate of Agricultural Research and Policies.
In 2015, with the purchase of 2 sire and 3 dam pure line parent material from an international breeding company, the studies were shifted to the fast growing broiler parent production and breeding field at Eskişehir Transitional Zone Agricultural Research Institute (EGKTAE). Studies were carried out in the fields of reproduction, selection, grand parent and parent production in pure lines between 2015-2025. On the other hand, the parents obtained were shared with the private sector. Doctoral and master's theses, international and national publications were made by utilizing the existing pure lines related to breeding studies. The material used in broiler breeding studies was registered as Anadolu-T. Within the scope of research and development studies, a device that provides automation of individual feed utilization test was developed at EGKTAE and started to be used in breeding studies. When the appropriate reproduction processes of the existing material are carried out, there is a potential for 25-30% of the genetic material used in broiler production in our country to be provided from Anadolu-T parents. In particular, in terms of epidemic diseases and pandemics seen in humans and animals, security risks and reducing external dependency, protecting the material and developing similar characteristics to commercial genotypes are important in terms of food safety.

Keywords: *Anadolu-T, Breeding studies, feed utilization test unit, food safety*

Inroduction

The majority of the increase in poultry meat production in the world originates from Asian countries. Especially the production increases in China, India, Japan, South Korea, Turkey and Iran have a significant contribution to this increase. While the market shares in North America and Europe have declined in poultry meat production, Brazil has become one of the important centers of poultry meat production in South America. Chicken meat production level in the world ranks second after pork. However, with the increases in chicken meat since 2010, the share of poultry meat in meat production rose to the first place in 2017. The majority of poultry meat comes from chicken meat. Considering that the increase in production in some species has stopped, in others there has been a decline and that some importing countries do not consume pork, poultry meat production is expected to increase in the future. Only two of the top 10 countries in world chicken meat production in 1970 were developing countries (Brazil and China). During this period, the USA provided approximately 31% of the world poultry meat production. In 2005, five of the top 10 countries were developing countries (China, Brazil, Mexico, India, and Iran) and three of them in Asia. Although the USA still maintains its leading position, China and Brazil ranked 2nd and 3rd. No other EU country produces chicken meat as much as Türkiye. Important chicken meat importing countries are in the Middle East, Africa, Central Asia, the Caucasus and some regions of the Russian Federation. In these markets, Turkey needs to compete with classical exporting countries such as Brazil, the USA and EU countries, as well as with Iran and Russia (Sarıca et al, 2018).

Turkish Science and Technology Publishing (TURSTEP)
www.turstep.com.tr

Table 1. Countries ranking first in chicken meat production (1000 tons)

Countries	1970	1980	1990	2000	2010	2015	2020	2021	2022	2023
USA	4.465	6.487	10.759	16.416	16.563	18.402	20.515	19.004	19.984	19.902
China	971	1.663	3.740	12.689	12.550	12.075	15.294	15.413	15.000	15.477
Brazil	378	1.397	2.422	6.125	12.312	13.149	13.747	14.329	14.524	14.833
EU	3.533	5.611	6.355	8.204	9.202	11.415	11.037	10.765	10.791	11.066
Russia	-	-	-	754	2.310	4.087	4.577	4.617	5.308	5.340
India	81	112	361	864	2.650	3.263	4.473	4.461	4.995	5.019
Indonesia	56	168	498	804	1.465	2.030	3.642	3.456	4.109	4.444
Mexico	192	399	750	1.825	2.822	2.962	3.579	3.669	3.782	3.888
Japan	490	1.128	1.391	1.194	1.417	2.132	2.332	2.343	2.371	2.384
Türkiye	97	240	402	643	1.420	1.909	2.138	2.246	2.418	2.329
Argentina	177	281	322	958	1.680	1.969	2.219	2.294	2.319	2.287
Iran	87	211	380	803	1.666	2.053	2.430	2.106	2.090	2.067
England	495	615	790	1.215	1.376	1.521	1.794	1.841	1.847	1.851
Thailand	196	287	575	1.045	1.220	1.713	1.748	1.796	1.807	1.845
Total	11.218	18.599	28.745	53.539	68.653	78.680	89.525	88.430	91.345	92.732
Others	1.922	4.298	6.671	5.153	18.729	25.121	30.936	31.991	32.537	33.798
World	13.140	22.897	35.416	58.692	87.382	103.801	120.461	120.421	123.882	126.530

FAO, 2025.

Almost all of the hybrid material of chicken meat and eggs produced in Türkiye is imported as parents or partially grandparents. Parent stock (PS) and partially grand-parent (GP) stock are imported in increasing numbers every year for the production of hybrids used in egg and chicken meat production. Although Türkiye is among the few countries in the world in commercial egg and broiler chicken production, no significant progress has been made in breeder production to date. Breeding material is provided from abroad at a rate of 95.0-97.5% in egg production and 98.0% in poultry meat production (Sarıca et al., 2011; Sarıca et al., 2012; Sarıca et al., 2018; Sarıca et al., 2019a).

Based on these studies, broiler chicken breeding studies were restarted in 2015 at Eskişehir Transitional Zone Agricultural Research Institute (EGKTAE). These studies are still continuing with the selection of 3 dam and 2 sire lines, as well as grandparent and parent production. The first parent production was carried out in 2018 and shared with the private sector. The parent material, registered as ANADOLU-T, continued to be shared with the private sector until 2023. Especially in 2022, breeding companies have declared that they will reduce their breeding material exports to Turkey by 25-30%, which once again shows the importance of these breeding operations.

Breeding Studies with Pure Lines (2015-2025)

At the meeting held on 21.06.2011 at the General Directorate of Agricultural Research and Policies (TAGEM) with the participation of private sector, public and university partners, it was decided to restart broiler chicken breeding studies. It is planned to start the studies with the production of slow-growing broiler chicken parents. For this purpose, a poultry unit affiliated with Eskişehir Transitional Zone Agricultural Research Institute (EGKTAE) was established. The aim of the project is to provide a fast growing dam line and to bring the BAR and RIR lines in Ankara Poultry Research Institute into operation. Attempts to provide genetic material resulted in the importation of 3 fast growing dam and 2 sire lines. Therefore, the studies were changed to realize commercial broiler production. Multiplication processes were provided in the first year with the incubation of hatching eggs in August 2015, and processes such as selection, parent production and hybrid tests are continuing between 2016-2024 (Sarıca et al., 2016a; Sarıca et al., 2017; Sarıca et al., 2019b, Sarıca et al., 2019c).

Description of the Breeding Unit

The application area of the broiler parent breeding project is located within the borders of Mahmudiye district of Eskişehir province. Breeding farm consists of a pure line breeding unit and a hatchery 1 km away. Farm planned to be established on a land of 80 decares;

Administrative unit: It consists of dining hall, laboratory, personnel entrance disinfection unit, guest house and offices.

Chick rearing houses: There are 4 fully controlled rearing houses, each with 176 cages. Each poultry house has a capacity of 2000-2500 chicks. There is 1 rearing poultry house added to these poultry houses with 378 cages (5000-6000 chick capacity).

Pure line breeding house: It consists of 5088 cage units and 700 cock cage units. Broiler chickens between 5-10 weeks of age are reared in this house. .

Pedigree houses: There are 2 poultry houses with 160 family pens for 9-12 hens with 1 cock.

Pure line rooster houses: There are 2 poultry houses with 950 individual floor pens for individual rearing of cocks.

Grand-parent houses: There are 4 houses: 1 grower house (capacity of 5500 chickens), 1 dam line laying house (capacity of 5500 chickens), 2 sire line houses (capacities of 2000 chickens).
Hatchery: It is planned as a separate unit with a hatching capacity of 110.000 chicks, where the desired conditions for egg storage can be met. It has an automatic vaccination system.
Other units: There is an 800 m^2 closed warehouse, 2 hygiene units where 26 people can shower at the same time, vehicle hygiene entrance and security guard building.
Personnel: There is 1 coordinator Veterinarian, 6 Zootechnicians Agricultural Engineers and 1 Technician who provide management and research services in the breeding unit. Operations in the chicken houses are carried out by 35 workers, the number of whom varies according to periods. There is 1 Veterinarian and 9 technical personnel in the hatchery. There are permanent security personnel in the poultry house and hatchery units.

Characteristics of Pure Lines
Some characteristics of the pure lines used in breeding studies and numerical values of the base population are given in Table 2.

Table 2. Characteristics of imported parental lines and the number of first chicks produced (Sarıca et al., 2016b; Noubandiguim et al., 2021)

Pure line	Wing feathering	Number of chicks
Main dam line (A1)	Slow feathering	2086
Dam line (A2)	Fast feathering	371
Dam line (A3)	Slow feathering	188
Main sire line (B1)	Fast feathering	546
Sire line (B2)	Fast feathering	928

Selection Methods
Selection for each pure line is carried out in 3 stages. In the first stage, selection is applied according to body weight in pure lines that are ad libitum-fed until 3 weeks of age. In the second stage, selection is applied according to body weights at 5 or 6 weeks of age. In the third stage, the selection index value for cocks and hens is created by determining the breast width and length with the individual FCR test between 5-8 weeks of age. Families of 1 cock and 10 hens are formed for pedigreed production from selected cocks and hens. During the laying period, a selection is made at the family level according to the fertilization capacity of the cocks, and the final selection is applied by taking into account the egg production of the dam lines.
The material was registered as "ANADOLU-T" with the Official Gazette of the Republic of Turkey dated December 5, 2020 and numbered 31325.

Some Characteristics of the Pure Lines
Data on the parental characteristics of pure lines has been received since 2016. Instead of the results obtained in the breeding enterprise (EGKTAE), data obtained from a doctoral thesis were used in this study (Erensoy, 2022).

Table 3. Growth and laying period characteristics of pure lines (Erensoy, 2022; Erensoy and Sarıca, 2022; M: Male, F: Female)

Traits	Sex	Dam lines			Pure lines	
		A1	A2	A3	B1	B2
Body weight (8 weeks, g)	M	491.1	584.9	558.4	570.0	574.1
	F	465.7	536.5	551.2	540.2	544.6
Body weight (23 weeks, g)	M	3117.7	3319.7	3167.0	3445.7	3368.3
	F	2525.9	2562.2	2479.5	2691.5	2639.8
Body weight (60 weeks, g)	M	4586.0	4456.0	4002.0	4472.0	5042.0
	F	4034.6	4724.0	4488.6	4290.1	4855.3
Feed intake (g, 0-23 weeks)	M	11564	11438	11480	11172	11200
	F	9555	9632	9583	9506	9597
Livability (%, 0-23 weeks)		100	93.3	100.0	96.7	96.7
Livability (%, 24-64 weeks)		100	91.7	100.0	93.8	100.0
Egg production (24-64 weeks)		188	160	160	120	124
Egg weight (g)		66.6	67.9	65.1	67.3	68.2
Feed intake (g/day, 24-64 weeks)	M	140.1	150.1	140.1	137.5	137.5
	F	160.75	157.7	160.6	157.1	157.1

Some Characteristics of the Parents

Parents produced in the breeding enterprise were given to some integrated enterprises for trial purposes, and the parent efficiency was not tested in the breeding enterprise. All two-way crossed parental lines (6 sire lines and 2 dam lines) that could be obtained by reciprocal crossbreeding in pure lines were tested in a doctoral study (Erensoy, 2022). The genotype, which also allows sexing in day-old chicks according to wing feathering rate, is coded as ANADOLU-T. Some growth and laying period characteristics of these parent lines produced up to 64 weeks of age are given in Table 3 and 4.

Table 3. Growth and egg production characteristics of the female parents (Erensoy, 2022; Erensoy and Sarıca, 2022)

Traits	Dam line	Sire line
Body weight (8 weeks, g)	967.9	1340.4
Body weight (23 weeks, g)	2586.7	3329.8
Body weight (60 weeks, g)	4117.3	4463.2
Feed intake (g, 0-23 weeks)	11361	9093
Livability (%, 0-23 weeks)	88.9	96.7
Livability (%, 24-64 weeks)	96.3	100
Egg production (24-64 weeks)	161.9	-
Egg weight (g)	65.2	-
Feed intake (g/day, 24-64 weeks)	159.1	140.0

Table 4. Hatching results of ANADOLU-T and Ross-308 parents at 32 and 52 weeks of age (2 hatchings; Erensoy, 2022; Erensoy and Sarıca, 2022)

Genotype	Fertility (%)		Hatchability of fertile eggs (%)		Hatchability of set eggs (%)	
	32 weeks	52 weeks	32 weeks	52 weeks	32 weeks	52 weeks
ANADOLU-T	100.0	90.8	92.4	76.1	91.7	69.2
ANADOLU-T commercial	94.2	85.0	80.8	79.4	70.0	67.5
Ross-308	96.7	78.2	90.0	87.4	82.5	69.2

(Hatching eggs of ANADOLU-T commercial breeders were purchased from the private sector).

Broiler characteristics and comparison with commercial genotypes

Chicks obtained after selection in pure lines since 2016 are compared with a commercial genotype (Ross or Cobb) in terms of broiler characteristics. In addition to growth characteristics, carcass characteristics and body defects are also considered in these studies. The data obtained is also used for selection studies for the next generations. In the sire lines, 10-12 chicks from each family were also compared for broiler traits. The growth characteristics of ANADOLU-T hybrid produced from 12 hybrid groups by Erensoy (2022), ANADOLU-T Commercial and Ross-308 hybrids obtained from commercial enterprises at 42 days of age are given in Table 5.

Table 5. Performance of ANADOLU-T pure lines, commercial broilers and Ross-308 at 42 days of age (male-female mixed; Erensoy, 2022; Erensoy and Sarıca, 2023)

Genotype	Body weight (g)		Feed intake (g)		FCR		Livability (%)	
	32 weeks	52 weeks	32 weeks	52 weeks	32 weeks	52 weeks	32 weeks	52 weeks
A1-dam line	2307.7	2736.1	3971.0	4597.3	1.713	1.681	95.3	98.3
A2-dam line	2505.0	2333.8	4138.0	3954.7	1.653	1.695	93.3	98.3
A3-dam line	2371.5	2492.2	4130.1	4168.0	1.743	1.673	98.7	100.0
B1-sire line	2763.9	2773.6	4628.4	4756.2	1.687	1.718	95.3	96.7
B2-sire line	2663.8	2677.0	4558.3	4494.4	1.733	1.686	96.0	90.0
Anadolu-T-hybrid	2790.1	2784.6	4636.2	4709.9	1.660	1.692	96.0	100.0
Anadolu-T-hybrid	2773.3	2858.0	4695.7	4800.9	1.697	1.680	96.7	96.7
Ross-308	2961.2	3136.2	4422.2	4485.5	1.520	1.430	97.3	100.0

Conclusion and Recommendations

Promising results were obtained from the studies carried out with pure lines introduced to Turkey in 2015. More than 250.000 parent stock breeders were given to the private sector between 2018-2023. It is thought that 10-15% of the broiler breeders requirement of our country can be met from this material by developing the current capacity at the grand-parent level. For these;

- Slaughtering broilers at an earlier age (33-35 days) due to the lack of feed efficiency at late slaughter (42 days),
- Compensating for vaccination-induced mortality in the first weeks by vaccination during hatching,
- Developing more effective selection strategies for feed efficiency and reproduction traits,
- By establishing a larger grand-parent facility, commercial companies can be provided with chicks at the desired capacity at any time of the year.

Considering these issues, a lifetime feed efficiency unit was developed and started to be used in 2023 with the TÜBİTAK-TAGEM project. On the other hand, genomic studies on pure lines will be initiated in 2024 and it is aimed to be used together with the classical selection practices.

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Recent studies and future expectations in broiler breeding in Turkey

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Abstract

Turkey ranks in the top 10 in broiler production in the world. Almost all of the genetic material used in production in our country is provided by commercial international breeding companies. In order to reduce complete external dependency in this field and to have improved genetic stocks, broiler breeding studies have been restarted in Turkey since 2010. The studies, which started with a project (TÜBİTAK 109O334) to produce slow-growing broiler parents, have been put into practice by the Ministry of Agriculture and Forestry, General Directorate of Agricultural Research and Policies.
In 2015, with the purchase of 2 sire and 3 dam pure line parent material from an international breeding company, the studies were shifted to the fast growing broiler parent production and breeding field at Eskişehir Transitional Zone Agricultural Research Institute (EGKTAE). Studies were carried out in the fields of reproduction, selection, grand parent and parent production in pure lines between 2015-2025. On the other hand, the parents obtained were shared with the private sector. Doctoral and master's theses, international and national publications were made by utilizing the existing pure lines related to breeding studies. The material used in broiler breeding studies was registered as Anadolu-T. Within the scope of research and development studies, a device that provides automation of individual feed utilization test was developed at EGKTAE and started to be used in breeding studies. When the appropriate reproduction processes of the existing material are carried out, there is a potential for 25-30% of the genetic material used in broiler production in our country to be provided from Anadolu-T parents. In particular, in terms of epidemic diseases and pandemics seen in humans and animals, security risks and reducing external dependency, protecting the material and developing similar characteristics to commercial genotypes are important in terms of food safety.

Keywords: *Anadolu-T, Breeding studies, feed utilization test unit, food safety*

Inroduction

The majority of the increase in poultry meat production in the world originates from Asian countries. Especially the production increases in China, India, Japan, South Korea, Turkey and Iran have a significant contribution to this increase. While the market shares in North America and Europe have declined in poultry meat production, Brazil has become one of the important centers of poultry meat production in South America. Chicken meat production level in the world ranks second after pork. However, with the increases in chicken meat since 2010, the share of poultry meat in meat production rose to the first place in 2017. The majority of poultry meat comes from chicken meat. Considering that the increase in production in some species has stopped, in others there has been a decline and that some importing countries do not consume pork, poultry meat production is expected to increase in the future. Only two of the top 10 countries in world chicken meat production in 1970 were developing countries (Brazil and China). During this period, the USA provided approximately 31% of the world poultry meat production. In 2005, five of the top 10 countries were developing countries (China, Brazil, Mexico, India, and Iran) and three of them in Asia. Although the USA still maintains its leading position, China and Brazil ranked 2nd and 3rd. No other EU country produces chicken meat as much as Türkiye. Important chicken meat importing countries are in the Middle East, Africa, Central Asia, the Caucasus and some regions of the Russian Federation. In these markets, Turkey needs to compete with classical exporting countries such as Brazil, the USA and EU countries, as well as with Iran and Russia (Sarıca et al, 2018).

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Table 1. Countries ranking first in chicken meat production (1000 tons)

Countries	1970	1980	1990	2000	2010	2015	2020	2021	2022	2023
USA	4.465	6.487	10.759	16.416	16.563	18.402	20.515	19.004	19.984	19.902
China	971	1.663	3.740	12.689	12.550	12.075	15.294	15.413	15.000	15.477
Brazil	378	1.397	2.422	6.125	12.312	13.149	13.747	14.329	14.524	14.833
EU	3.533	5.611	6.355	8.204	9.202	11.415	11.037	10.765	10.791	11.066
Russia	-	-	-	754	2.310	4.087	4.577	4.617	5.308	5.340
India	81	112	361	864	2.650	3.263	4.473	4.461	4.995	5.019
Indonesia	56	168	498	804	1.465	2.030	3.642	3.456	4.109	4.444
Mexico	192	399	750	1.825	2.822	2.962	3.579	3.669	3.782	3.888
Japan	490	1.128	1.391	1.194	1.417	2.132	2.332	2.343	2.371	2.384
Türkiye	97	240	402	643	1.420	1.909	2.138	2.246	2.418	2.329
Argentina	177	281	322	958	1.680	1.969	2.219	2.294	2.319	2.287
Iran	87	211	380	803	1.666	2.053	2.430	2.106	2.090	2.067
England	495	615	790	1.215	1.376	1.521	1.794	1.841	1.847	1.851
Thailand	196	287	575	1.045	1.220	1.713	1.748	1.796	1.807	1.845
Total	11.218	18.599	28.745	53.539	68.653	78.680	89.525	88.430	91.345	92.732
Others	1.922	4.298	6.671	5.153	18.729	25.121	30.936	31.991	32.537	33.798
World	13.140	22.897	35.416	58.692	87.382	103.801	120.461	120.421	123.882	126.530

FAO, 2025.

Almost all of the hybrid material of chicken meat and eggs produced in Türkiye is imported as parents or partially grandparents. Parent stock (PS) and partially grand-parent (GP) stock are imported in increasing numbers every year for the production of hybrids used in egg and chicken meat production. Although Türkiye is among the few countries in the world in commercial egg and broiler chicken production, no significant progress has been made in breeder production to date. Breeding material is provided from abroad at a rate of 95.0-97.5% in egg production and 98.0% in poultry meat production (Sarıca et al., 2011; Sarıca et al., 2012; Sarıca et al., 2018; Sarıca et al., 2019a).

Based on these studies, broiler chicken breeding studies were restarted in 2015 at Eskişehir Transitional Zone Agricultural Research Institute (EGKTAE). These studies are still continuing with the selection of 3 dam and 2 sire lines, as well as grandparent and parent production. The first parent production was carried out in 2018 and shared with the private sector. The parent material, registered as ANADOLU-T, continued to be shared with the private sector until 2023. Especially in 2022, breeding companies have declared that they will reduce their breeding material exports to Turkey by 25-30%, which once again shows the importance of these breeding operations.

Breeding Studies with Pure Lines (2015-2025)

At the meeting held on 21.06.2011 at the General Directorate of Agricultural Research and Policies (TAGEM) with the participation of private sector, public and university partners, it was decided to restart broiler chicken breeding studies. It is planned to start the studies with the production of slow-growing broiler chicken parents. For this purpose, a poultry unit affiliated with Eskişehir Transitional Zone Agricultural Research Institute (EGKTAE) was established. The aim of the project is to provide a fast growing dam line and to bring the BAR and RIR lines in Ankara Poultry Research Institute into operation. Attempts to provide genetic material resulted in the importation of 3 fast growing dam and 2 sire lines. Therefore, the studies were changed to realize commercial broiler production. Multiplication processes were provided in the first year with the incubation of hatching eggs in August 2015, and processes such as selection, parent production and hybrid tests are continuing between 2016-2024 (Sarıca et al., 2016a; Sarıca et al., 2017; Sarıca et al., 2019b, Sarıca et al., 2019c).

Description of the Breeding Unit

The application area of the broiler parent breeding project is located within the borders of Mahmudiye district of Eskişehir province. Breeding farm consists of a pure line breeding unit and a hatchery 1 km away. Farm planned to be established on a land of 80 decares;

Administrative unit: It consists of dining hall, laboratory, personnel entrance disinfection unit, guest house and offices.

Chick rearing houses: There are 4 fully controlled rearing houses, each with 176 cages. Each poultry house has a capacity of 2000-2500 chicks. There is 1 rearing poultry house added to these poultry houses with 378 cages (5000-6000 chick capacity).

Pure line breeding house: It consists of 5088 cage units and 700 cock cage units. Broiler chickens between 5-10 weeks of age are reared in this house. .

Pedigree houses: There are 2 poultry houses with 160 family pens for 9-12 hens with 1 cock.

Pure line rooster houses: There are 2 poultry houses with 950 individual floor pens for individual rearing of cocks.

Grand-parent houses: There are 4 houses: 1 grower house (capacity of 5500 chickens), 1 dam line laying house (capacity of 5500 chickens), 2 sire line houses (capacities of 2000 chickens).
Hatchery: It is planned as a separate unit with a hatching capacity of 110.000 chicks, where the desired conditions for egg storage can be met. It has an automatic vaccination system.
Other units: There is an 800 m^2 closed warehouse, 2 hygiene units where 26 people can shower at the same time, vehicle hygiene entrance and security guard building.
Personnel: There is 1 coordinator Veterinarian, 6 Zootechnicians Agricultural Engineers and 1 Technician who provide management and research services in the breeding unit. Operations in the chicken houses are carried out by 35 workers, the number of whom varies according to periods. There is 1 Veterinarian and 9 technical personnel in the hatchery. There are permanent security personnel in the poultry house and hatchery units.

Characteristics of Pure Lines
Some characteristics of the pure lines used in breeding studies and numerical values of the base population are given in Table 2.

Table 2. Characteristics of imported parental lines and the number of first chicks produced (Sarıca et al., 2016b; Noubandiguim et al., 2021)

Pure line	Wing feathering	Number of chicks
Main dam line (A1)	Slow feathering	2086
Dam line (A2)	Fast feathering	371
Dam line (A3)	Slow feathering	188
Main sire line (B1)	Fast feathering	546
Sire line (B2)	Fast feathering	928

Selection Methods
Selection for each pure line is carried out in 3 stages. In the first stage, selection is applied according to body weight in pure lines that are ad libitum-fed until 3 weeks of age. In the second stage, selection is applied according to body weights at 5 or 6 weeks of age. In the third stage, the selection index value for cocks and hens is created by determining the breast width and length with the individual FCR test between 5-8 weeks of age. Families of 1 cock and 10 hens are formed for pedigreed production from selected cocks and hens. During the laying period, a selection is made at the family level according to the fertilization capacity of the cocks, and the final selection is applied by taking into account the egg production of the dam lines.
The material was registered as "ANADOLU-T" with the Official Gazette of the Republic of Turkey dated December 5, 2020 and numbered 31325.

Some Characteristics of the Pure Lines
Data on the parental characteristics of pure lines has been received since 2016. Instead of the results obtained in the breeding enterprise (EGKTAE), data obtained from a doctoral thesis were used in this study (Erensoy, 2022).

Table 3. Growth and laying period characteristics of pure lines (Erensoy, 2022; Erensoy and Sarıca, 2022; M: Male, F: Female)

Traits	Sex	Dam lines			Pure lines	
		A1	A2	A3	B1	B2
Body weight (8 weeks, g)	M	491.1	584.9	558.4	570.0	574.1
	F	465.7	536.5	551.2	540.2	544.6
Body weight (23 weeks, g)	M	3117.7	3319.7	3167.0	3445.7	3368.3
	F	2525.9	2562.2	2479.5	2691.5	2639.8
Body weight (60 weeks, g)	M	4586.0	4456.0	4002.0	4472.0	5042.0
	F	4034.6	4724.0	4488.6	4290.1	4855.3
Feed intake (g, 0-23 weeks)	M	11564	11438	11480	11172	11200
	F	9555	9632	9583	9506	9597
Livability (%, 0-23 weeks)		100	93.3	100.0	96.7	96.7
Livability (%, 24-64 weeks)		100	91.7	100.0	93.8	100.0
Egg production (24-64 weeks)		188	160	160	120	124
Egg weight (g)		66.6	67.9	65.1	67.3	68.2
Feed intake (g/day, 24-64 weeks)	M	140.1	150.1	140.1	137.5	137.5
	F	160.75	157.7	160.6	157.1	157.1

Some Characteristics of the Parents

Parents produced in the breeding enterprise were given to some integrated enterprises for trial purposes, and the parent efficiency was not tested in the breeding enterprise. All two-way crossed parental lines (6 sire lines and 2 dam lines) that could be obtained by reciprocal crossbreeding in pure lines were tested in a doctoral study (Erensoy, 2022). The genotype, which also allows sexing in day-old chicks according to wing feathering rate, is coded as ANADOLU-T. Some growth and laying period characteristics of these parent lines produced up to 64 weeks of age are given in Table 3 and 4.

Table 3. Growth and egg production characteristics of the female parents (Erensoy, 2022; Erensoy and Sarıca, 2022)

Traits	Dam line	Sire line
Body weight (8 weeks, g)	967.9	1340.4
Body weight (23 weeks, g)	2586.7	3329.8
Body weight (60 weeks, g)	4117.3	4463.2
Feed intake (g, 0-23 weeks)	11361	9093
Livability (%, 0-23 weeks)	88.9	96.7
Livability (%, 24-64 weeks)	96.3	100
Egg production (24-64 weeks)	161.9	-
Egg weight (g)	65.2	-
Feed intake (g/day, 24-64 weeks)	159.1	140.0

Table 4. Hatching results of ANADOLU-T and Ross-308 parents at 32 and 52 weeks of age (2 hatchings; Erensoy, 2022; Erensoy and Sarıca, 2022)

Genotype	Fertility (%)		Hatchability of fertile eggs (%)		Hatchability of set eggs (%)	
	32 weeks	52 weeks	32 weeks	52 weeks	32 weeks	52 weeks
ANADOLU-T	100.0	90.8	92.4	76.1	91.7	69.2
ANADOLU-T commercial	94.2	85.0	80.8	79.4	70.0	67.5
Ross-308	96.7	78.2	90.0	87.4	82.5	69.2

(Hatching eggs of ANADOLU-T commercial breeders were purchased from the private sector).

Broiler characteristics and comparison with commercial genotypes

Chicks obtained after selection in pure lines since 2016 are compared with a commercial genotype (Ross or Cobb) in terms of broiler characteristics. In addition to growth characteristics, carcass characteristics and body defects are also considered in these studies. The data obtained is also used for selection studies for the next generations. In the sire lines, 10-12 chicks from each family were also compared for broiler traits. The growth characteristics of ANADOLU-T hybrid produced from 12 hybrid groups by Erensoy (2022), ANADOLU-T Commercial and Ross-308 hybrids obtained from commercial enterprises at 42 days of age are given in Table 5.

Table 5. Performance of ANADOLU-T pure lines, commercial broilers and Ross-308 at 42 days of age (male-female mixed; Erensoy, 2022; Erensoy and Sarıca, 2023)

Genotype	Body weight (g)		Feed intake (g)		FCR		Livability (%)	
	32 weeks	52 weeks	32 weeks	52 weeks	32 weeks	52 weeks	32 weeks	52 weeks
A1-dam line	2307.7	2736.1	3971.0	4597.3	1.713	1.681	95.3	98.3
A2-dam line	2505.0	2333.8	4138.0	3954.7	1.653	1.695	93.3	98.3
A3-dam line	2371.5	2492.2	4130.1	4168.0	1.743	1.673	98.7	100.0
B1-sire line	2763.9	2773.6	4628.4	4756.2	1.687	1.718	95.3	96.7
B2-sire line	2663.8	2677.0	4558.3	4494.4	1.733	1.686	96.0	90.0
Anadolu-T-hybrid	2790.1	2784.6	4636.2	4709.9	1.660	1.692	96.0	100.0
Anadolu-T-hybrid	2773.3	2858.0	4695.7	4800.9	1.697	1.680	96.7	96.7
Ross-308	2961.2	3136.2	4422.2	4485.5	1.520	1.430	97.3	100.0

Conclusion and Recommendations

Promising results were obtained from the studies carried out with pure lines introduced to Turkey in 2015. More than 250.000 parent stock breeders were given to the private sector between 2018-2023. It is thought that 10-15% of the broiler breeders requirement of our country can be met from this material by developing the current capacity at the grand-parent level. For these;

- Slaughtering broilers at an earlier age (33-35 days) due to the lack of feed efficiency at late slaughter (42 days),
- Compensating for vaccination-induced mortality in the first weeks by vaccination during hatching,
- Developing more effective selection strategies for feed efficiency and reproduction traits,
- By establishing a larger grand-parent facility, commercial companies can be provided with chicks at the desired capacity at any time of the year.

Considering these issues, a lifetime feed efficiency unit was developed and started to be used in 2023 with the TÜBİTAK-TAGEM project. On the other hand, genomic studies on pure lines will be initiated in 2024 and it is aimed to be used together with the classical selection practices.

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Turkish Viticulture And Its Status In The World

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Abstract

Grape production of the world has observed to be around 72 million tons in nearly 6.6 million ha area by 2023. The largest area under vines will be in Spain, with 913,000 hectares, followed by France, Italy, China and Türkiye. In terms of production, the highest value is in China with 13.5 million tonnes, followed by Italy, France, USA and Spain. Türkiye ranks fifth in the world with 5.7% of the total vineyard area. In terms of grape production, it ranks seventh with 4.7% of the total world production. Approximately 53% of the total grape production in the country is used for table grapes, 29% for seedless raisins, 9% for seeded raisins and 9% for wine-must. It was found that the vineyard area in Türkiye decreased by 9.4% and grape production by 13.6% over the last five years (2018-2023). Due to unfavorable climatic conditions and the resulting mildew damage in the 2023 season, production has decreased. Türkiye is the leading exporter of high-quality sultana raisins. The most common grape variety is Sultan 7 (*V. Vinifera* L.), developed by the Manisa Viticulture Research Institute. Over the past decade, seedless raisin (sultana raisin) production has averaged around 1.1 million tons, accounting for 29% of total grape production. Türkiye, the world's leading raisin exporter, also accounts for about 30 percent of the world's raisin export. Over the last ten years, it has exported around 240,000 tonnes of dried grapes, worth an average of $458 million. The Aegean region alone accounts for 39.2% of the country's total grape production and 40.3% of the total area under vines. Moreover, Manisa province is the country's grape capital, producing about 70% of the region's total grape production and 91% of seedless raisin production.

Key Words: *Grape production, vineyards, trade, viticulture*

Türkiye Bağciliği Ve Dünyadaki Yeri

Özet

2023 yılı itibarıyla Dünyada yaklaşık 6.6 milyon ha alanda 72 milyon ton yaş üzüm üretimi olduğu gözlenmiştir. En fazla bağ alanı 913.000 ha ile İspanya'da bulunmakta ve bunu sırasıyla Fransa, İtalya, Çin ve Türkiye takip etmektedir. Üretim bakımından ise en yüksek değer 13.5 milyon ton ile Çin'de gerçekleşmekte ve sonrasında İtalya, Fransa, ABD, İspanya yer almaktadır. Türkiye, toplam bağ alanının %5.7'sine sahip olurken dünyada beşinci sıradadır. Üzüm üretimi bakımından ise dünyadaki toplam üretimin %4.7'sine sahip olarak yedinci sırada bulunmaktadır. Ülkede üretilen toplam üzüm miktarının yaklaşık %53'ü sofralık, %29'u çekirdeksiz kuru üzüm, %9'u çekirdekli kuru üzüm ve %9'u da şaraplık-şıralık olarak değerlendirilmektedir. Son 5 yıl incelendiğinde, 2018-2023 yılları arasında Türkiye bağ alanının %9.4, üzüm üretim miktarının ise %13.6 azaldığı tespit edilmiştir. 2023 sezonunda yaşanan olumsuz iklim şartları ve buna bağlı meydana gelen mildiyö zararı üretimde azalmaya neden olmuştur. Türkiye, yüksek kaliteye sahip Sultana tipi kuru üzümü ile ihracatta lider konumda bulunurken en yaygın üzüm çeşidi Manisa Bağcılık Araştırma Enstitüsü tarafından geliştirilen Sultan 7 (*V. Vinifera* L.)'dir. Son on yılda çekirdeksiz üzüm üretimi (sultana kuru üzümü) ortalama 1.1 milyon ton civarında gerçekleşmiş ve bu değer toplam üzüm üretiminin %29'unu oluşturmuştur. Ayrıca dünyanın önde gelen kuru üzüm ihracatçısı olan Türkiye, küresel kuru üzüm ihracatının yaklaşık %30'unu gerçekleştirmektedir. Buna göre son on yılda ortalama 458 milyon dolar değerinde yaklaşık 240.000 ton kuru üzüm ihraç etmiştir. Ülkenin toplam üzüm üretiminin yaklaşık %39.2'si ile toplam bağ alanının %40.3'ü tek başına Ege Bölgesi'nden sağlanmaktadır. Bununla birlikte bölgedeki toplam üzüm üretiminin yaklaşık %70'ine ve çekirdeksiz kuru üzüm üretiminin %91'ine sahip olan Manisa ili ülkenin üzüm üretimi bakımından başkenti konumundadır.

Anahtar Kelimeler: *Üzüm üretimi, bağ alanı, ticaret, bağcılık*

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Climate Change and Plant Breeding: Preparing for the Future

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Abstract

The food security of nations plays a determining role in today's and tomorrow's global agenda. Agriculture, which is the guarantor of food security, ranks among the sectors most affected by ongoing climate change. This critical environmental issue is broadly transforming weather patterns, temperatures, and ecosystems worldwide, impacting terrestrial and marine habitats. These gradual, long-term climatic shifts will inevitably influence agri-food systems, food production, and human livelihoods. Climate change, which has engulfed the entire world, makes the effects of abiotic and biotic stress conditions on plants more apparent. Unlike the gradually observed climatic changes over the years, the increasing frequency of extreme events makes the rapid development of new plant varieties essential. Considering the fact that the world has already warmed by 1°C compared to pre-industrial levels, it can be argued that—without a reduction in greenhouse gas emissions—this value will rise sharply after 2030. The increase in temperatures, the decrease in water resources, the irregularity of rainfall and, the insufficient rainfall during critical plant growth stages, the increase in severity of droughts, the aggressive spread of diseases, and the rapid emergence of new pathotypes underscore the paramount importance of plant breeding. In order to mitigate the agricultural impacts of climate change, it is essential not only to protect agricultural lands and modernize irrigation techniques but also- and most importantly- to develop resilient plant species. In addition to developing plant species resistant to heat, drought, cold and salinity, developing plant species resistant to diseases and pests, and introducing new productive and high-quality varieties to the market are indispensable for plant breeding. This approach enables better management of agricultural inputs and water needs while promoting soil health and reclamation. In addition, with climate-compatible plant breeding studies, more effective plant production patterns are created in agricultural production systems. Ensuring food security, maintaining ecological continuity, and effectively utilizing agricultural lands are all achievable through plant breeding. The continuously advancing new technologies are effectively utilized in breeding and in solving agricultural problems, thereby allowing for the anticipation of challenges that may arise in the future.

Key words: *extreme weather events, development of new plant varieties, use of agricultural technology, sustainability, food supply security*

İklim Değişikliği Ve Bitki Islahi: Geleceğe Hazirlik

Özet

Ülkelerin gıda güvenliği bugün ve gelecekte dünya gündeminin belirleyicisi rolündedir. Gıda güvenliğinin teminatı tarım ise yaşanan iklim değişikliğinden en fazla etkilenen faaliyet alanlarının başında gelmektedir. Bu önemli çevresel sorun genel anlamda, dünya genelinde hava koşullarını, sıcaklıkları ve ekosistemleri dönüştürmekte, karasal ve denizel habitatları etkilemektedir. İklimde yavaş yavaş başlayan bu uzun vadeli değişiklikler tarım-gıda sistemlerini, gıda üretimini ve insanların geçim kaynaklarını etkileyecektir. Tüm dünyayı etkisi altına alan iklim değişikliği bitkilerin abiyotik ve biyotik stres koşullarından etkilenmesini daha görünür hale getirmektedir. İklimsel anlamda yaşanan ve yıllar bazında gözlemlenen değişimlerin aksine ekstrem olaylarda yaşanan artışlar yeni bitki çeşitlerinin hızla geliştirilmesini elzem kılmaktadır. Dünyanın sanayi öncesi döneme göre 1°C ısındığı gerçeği düşünülürse, sera gazı emilsiyonlarında azalma olmazsa 2030'dan sonra hızla bu değerin artacağından söz edilebilir. Sıcaklıkların artması, su kaynaklarının azalması, yağışların düzensizleşmesi ve bitkilerin ihtiyaç duyduğu dönemde yeterli yağış alamaması, kuraklığın her geçen gün şiddetini artırması, hastalıkların agresif bir şekilde yayılması ve yeni patotiplerinin hızla ortaya çıkması bitki ıslahının ne denli önemli olduğunu gözler önüne sermektedir. Tarımsal olarak iklim değişikliğinin etkilerinin azaltılması için tarım alanlarının korunmasının yanı sıra sulama tekniklerinin modernize edilmesi ve en önemlisi dayanıklı bitki türlerinin geliştirilmesi elzemdir. Sıcağa, kurağa, soğuğa ve tuzluluğa dayanıklı bitki türlerini geliştirmenin yanı sıra hastalık ve zararlılara dayanıklı bitki türlerini geliştirmek, verimli ve kaliteli yeni çeşitleri piyasaya sürmek bitki ıslahının vazgeçilmezidir. Bu sayede hem tarımsal girdi ve su ihtiyaçlarının yönetilmesinin sağlanması, hem de toprak sağlığı ve ıslahının gerçekleştirilmesi mümkündür. Bunların yanı sıra iklime uyumlu bitki ıslahı çalışmaları ile tarımsal üretim sistemlerinde bitki üretim desenlerinin daha etkin olarak oluşturulması sağlanmış olur. Gıda güvenliğinin teminatı, ekolojilerin devamlılığı ve tarım topraklarından efektif olarak faydalanılmasının sağlanması bitki ıslahı ile mümkündür. Her geçen gün geliştirilen yeni teknolojiler de ıslahta ve tarımsal sorunların çözümde etkin kullanılmakta ve gelecekte karşılaşılabilecek sorunlar bu sayede öngörülebilmektedir.

Anahtar kelimeler: *ekstrem hava olayları, yeni bitki çeşitlerinin geliştirilmesi, tarımsal teknolojilerin kullanımı, sürdürülebilirlik, gıda arz güvenliği*

ID: 781

Digital Agriculture

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Abstract

Agriculture has been a sector of strategic importance throughout human history. Today, with the increasing population, climate change, and other global factors, the digitalization process in agriculture has accelerated. The digitalization of the agricultural sector aims to enhance the efficiency of resources and ensure environmental sustainability through the integration of digital technologies such as sensors, robotic systems, and artificial intelligence. This digital transformation will enable agricultural production to be carried out more easily within the modern living conditions that younger generations currently experience and will continue to experience in the future. In this process, interdisciplinary technologies such as the Internet of Things, sensor technologies, artificial intelligence, geographic information systems, and decision support mechanisms play a critical role in achieving data-driven sustainable agriculture. The integration of these technologies through digitalization will create opportunities to further increase the efficiency and sustainability of resources in agriculture. This study comprehensively discusses the concept of digital agriculture and the technologies related to this concept. With Agriculture 4.0, advanced technologies such as sensors, artificial intelligence, big data, unmanned aerial vehicles and land vehicles have been integrated into the agricultural sector. This integration process plays a critical role in ensuring precision and efficiency in agriculture. While precision agriculture offers an approach to local production optimization based on environmental factors, smart agriculture is characterized by the inclusion of information technologies in decision support processes. Digital agriculture is a broader framework that encompasses the management of all agricultural processes through digital platforms and the guidance of artificial intelligence-based robotic systems.

Key Words: *Agriculture, Agricultural Technologies, Agriculture 4.0, Digital Agriculture, Precision Agriculture.*

Dijital Tarım

Özet

Tarım, insanlık tarihi boyunca stratejik öneme sahip bir sektör olmuştur. Günümüzde artan nüfus, iklim değişikliği ve diğer küresel etmenlerle birlikte tarımda dijitalleşme süreci hız kazanmıştır. Tarım sektöründeki dijitalleşme süreci, sensörler, robotik sistemler ve yapay zeka gibi dijital teknolojilerin entegrasyonu yoluyla, kaynakların verimliliğini artırmayı ve çevresel sürdürülebilirliği sağlamayı hedeflemektedir. Bu dijital dönüşüm, genç nesillerin sahip olduğu ve gelecekte sahip olacağı modern yaşam koşullarında tarımsal üretimin nispeten daha kolay bir şekilde gerçekleşmesine olanak tanıyacaktır. Bu süreçte disiplinler arası teknolojiler olan nesnelerin interneti, sensör teknolojileri, yapay zekâ, coğrafi bilgi sistemleri ve karar destek mekanizmaları, veri odaklı sürdürülebilir tarımın gerçekleştirilmesinde kritik bir rol oynamaktadır. Dijitalleşmenin bu teknolojilerle entegrasyonu ile oluşturduğu fırsatlar tarımda kaynakların verimliliğini ve sürdürülebilirliğini artıracaktır.
Bu çalışmada, dijital tarım kavramı ve bu kavrama bağlı teknolojiler kapsamlı bir biçimde ele alınmaktadır. Tarım 4.0 ile birlikte, sensörler, yapay zekâ, büyük veri, insansız hava araçları ve kara araçları gibi ileri teknolojiler tarım sektörüne entegre edilmiştir. Bu entegrasyon süreci, tarımda hassasiyet ve verimlilik sağlamak için kritik bir rol oynamaktadır. Hassas tarım, çevresel faktörlere dayalı olarak yerel üretim optimizasyonuna yönelik bir yaklaşım sunarken, akıllı tarım bilişim teknolojilerin karar destek süreçlerine dâhil edilmesiyle karakterize edilmektedir. Dijital tarım ise tüm tarımsal süreçlerin dijital platformlar aracılığıyla yönetilmesini ve yapay zeka tabanlı robotik sistemlerin yönlendirilmesini kapsayan daha geniş bir çerçevedir.

Anahtar Kelimeler: *Tarım, Tarım Teknolojileri, Tarım 5.0, Dijital Tarım, Hassas Tarım*

ID: 780

Developments In Layer Breeding

Ahmet UÇAR[1]*, Ahmet Nuri TAŞDEMİR[1], Mustafa Kemal ÖZER[1], Ökkeş DİNGİŞ[1], Veysel Murat YAKUT[1], Birhan BOYALI[1]

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In Türkiye, genetic research on egg production has been carried out by the Poultry Research Institute (PRI) since 1930. In 1995, 10 pure lines, including White Layers (Black, Brown, Blue and Maroon) and Brown Layers (Rır-I, Rır-II, Bar-I, Bar-II, Col. and Line-54), were brought to PRI from Canada. In 2010, 1 more white layer line (D-229) was brought from the Czech Republic. This line was selected for high egg production (D-229yyv) and low live weight (D-229dca) traits and two synthetic lines were created. Four layer hybrids named ATABEY, ATAK, ATAK-S and AKBAY have been registered from the existing lines. Breeding has been carried out on these lines for many years in terms of egg count, egg weight, age at sexual maturity and weight at sexual maturity. With these 4 basic features, the main target has been to increase the amount of eggs obtained per female in both pure lines and hybrids. In the last 10 years, 8.7, 10.9, 20.0, 13.7, 11.8, 12.7, 8.2, 9.4, 1.9, 18.9 and 14.3% progress has been achieved in the amount of eggs obtained per female in D-229yyv, D-229dca, Black, Blue, Maroon, Brown, COL., Line-54, Bar-I, Bar-II, Rır-I and Rır-II lines, respectively. As a result of the breeding activities it has carried out, PRI meets approximately 15% of the layer parents needed by our country. As a result, it is aimed to increase this required rate by further improving hybrid performances in the coming years with the breeding studies carried out.

Keywords: *Layer, Egg production, Breeding, Line, Hybrid*

Yumurtacı Tavuk Islahındaki Gelişmeler

Özet

Türkiye'de yumurta verimi üzerine genetik araştırmalar 1930'dan beri Tavukçuluk Araştırma Enstitüsü (TAE) tarafından yürütülmektedir. TAE'ye Kanada'dan 1995 yılında Beyaz Yumurtacı (Black, Brown, Blue ve Maroon) ve Kahverengi Yumurtacı (Rır-I, Rır-II, Bar-I, Bar-II, Col. ve Line-54) olmak üzere 10 saf hat getirilmiştir. 2010 yılında Çekya'dan 1 adet daha (D-229) beyaz yumurtacı hat getirilmiştir. Bu hat kendi içinde yüksek yumurta verimi (D-229yyv) ve düşük canlı ağırlık (D-229dca) özellikleri yönünde selekte edilerek iki sentetik hat oluşturulmuştur. Mevcut hatlardan ATABEY, ATAK, ATAK-S ve AKBAY isimli 4 adet yumurtacı hibrit tescil edilmiştir. Bu hatlar üzerinde uzun yıllardır yumurta sayısı, yumurta ağırlığı, cinsel olgunluk yaşı ve cinsel olgunluk ağırlığı özelliklerinde ıslah yapılmaktadır. Bu 4 temel özellik ile dişi başına elde edilen yumurta miktarının hem saf hatlarda hem de hibritlerde artırılması asıl hedef olmuştur. Son 10 yıllık süreçte D-229yyv, D-229dca, Black, Blue, Maroon, Brown, COL., Line-54, Bar-I, Bar-II, Rır-I ve Rır-II hatlarında dişi başına elde edilen yumurta miktarında sırasıyla %8.7, 10.9, 20.0, 13.7, 11.8, 12.7, 8.2, 9.4, 1.9, 18.9 ve 14.3 ilerleme sağlanmıştır. TAE yapmış olduğu ıslah faaliyetleri sonucunda ülkemizin ihtiyaç duyduğu yumurtacı ebeveynin yaklaşık %15'ini karşılamaktadır. Sonuç olarak, yapılan ıslah çalışmaları ile gelecek yıllarda hibrit performanslarının daha da geliştirilerek ihtiyaç duyulan bu oranın artırılması hedeflenmektedir.

Anahtar Kelimeler*: Yumurtacı, Yumurta verimi, Islah, Hat, Hibrit*

ID: 785

Turkish Viticulture And Its Status In The World

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Abstract

Grape production of the world has observed to be around 72 million tons in nearly 6.6 million ha area by 2023. The largest area under vines will be in Spain, with 913,000 hectares, followed by France, Italy, China and Türkiye. In terms of production, the highest value is in China with 13.5 million tonnes, followed by Italy, France, USA and Spain. Türkiye ranks fifth in the world with 5.7% of the total vineyard area. In terms of grape production, it ranks seventh with 4.7% of the total world production. Approximately 53% of the total grape production in the country is used for table grapes, 29% for seedless raisins, 9% for seeded raisins and 9% for wine-must. It was found that the vineyard area in Türkiye decreased by 9.4% and grape production by 13.6% over the last five years (2018-2023). Due to unfavorable climatic conditions and the resulting mildew damage in the 2023 season, production has decreased. Türkiye is the leading exporter of high-quality sultana raisins. The most common grape variety is Sultan 7 (*V. Vinifera* L.), developed by the Manisa Viticulture Research Institute. Over the past decade, seedless raisin (sultana raisin) production has averaged around 1.1 million tons, accounting for 29% of total grape production. Türkiye, the world's leading raisin exporter, also accounts for about 30 percent of the world's raisin export. Over the last ten years, it has exported around 240,000 tonnes of dried grapes, worth an average of $458 million. The Aegean region alone accounts for 39.2% of the country's total grape production and 40.3% of the total area under vines. Moreover, Manisa province is the country's grape capital, producing about 70% of the region's total grape production and 91% of seedless raisin production.

Key Words: *Grape production, vineyards, trade, viticulture*

Türkiye Bağciliği Ve Dünyadaki Yeri

Özet

2023 yılı itibarıyla Dünyada yaklaşık 6.6 milyon ha alanda 72 milyon ton yaş üzüm üretimi olduğu gözlenmiştir. En fazla bağ alanı 913.000 ha ile İspanya'da bulunmakta ve bunu sırasıyla Fransa, İtalya, Çin ve Türkiye takip etmektedir. Üretim bakımından ise en yüksek değer 13.5 milyon ton ile Çin'de gerçekleşmekte ve sonrasında İtalya, Fransa, ABD, İspanya yer almaktadır. Türkiye, toplam bağ alanının %5.7'sine sahip olurken dünyada beşinci sıradadır. Üzüm üretimi bakımından ise dünyadaki toplam üretimin %4.7'sine sahip olarak yedinci sırada bulunmaktadır. Ülkede üretilen toplam üzüm miktarının yaklaşık %53'ü sofralık, %29'u çekirdeksiz kuru üzüm, %9'u çekirdekli kuru üzüm ve %9'u da şaraplık-şıralık olarak değerlendirilmektedir. Son 5 yıl incelendiğinde, 2018-2023 yılları arasında Türkiye bağ alanının %9.4, üzüm üretim miktarının ise %13.6 azaldığı tespit edilmiştir. 2023 sezonunda yaşanan olumsuz iklim şartları ve buna bağlı meydana gelen mildiyö zararı üretimde azalmaya neden olmuştur. Türkiye, yüksek kaliteye sahip Sultana tipi kuru üzümü ile ihracatta lider konumda bulunurken en yaygın üzüm çeşidi Manisa Bağcılık Araştırma Enstitüsü tarafından geliştirilen Sultan 7 (*V. Vinifera* L.)'dir. Son on yılda çekirdeksiz üzüm üretimi (sultana kuru üzümü) ortalama 1.1 milyon ton civarında gerçekleşmiş ve bu değer toplam üzüm üretiminin %29'unu oluşturmuştur. Ayrıca dünyanın önde gelen kuru üzüm ihracatçısı olan Türkiye, küresel kuru üzüm ihracatının yaklaşık %30'unu gerçekleştirmektedir. Buna göre son on yılda ortalama 458 milyon dolar değerinde yaklaşık 240.000 ton kuru üzüm ihraç etmiştir. Ülkenin toplam üzüm üretiminin yaklaşık %39.2'si ile toplam bağ alanının %40.3'ü tek başına Ege Bölgesi'nden sağlanmaktadır. Bununla birlikte bölgedeki toplam üzüm üretiminin yaklaşık %70'ine ve çekirdeksiz kuru üzüm üretiminin %91'ine sahip olan Manisa ili ülkenin üzüm üretimi bakımından başkenti konumundadır.

Anahtar Kelimeler: *Üzüm üretimi, bağ alanı, ticaret, bağcılık*

ID: 778

Climate Change and Plant Breeding: Preparing for the Future

Humeyra YAMAN[1]

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Abstract

The food security of nations plays a determining role in today's and tomorrow's global agenda. Agriculture, which is the guarantor of food security, ranks among the sectors most affected by ongoing climate change. This critical environmental issue is broadly transforming weather patterns, temperatures, and ecosystems worldwide, impacting terrestrial and marine habitats. These gradual, long-term climatic shifts will inevitably influence agri-food systems, food production, and human livelihoods. Climate change, which has engulfed the entire world, makes the effects of abiotic and biotic stress conditions on plants more apparent. Unlike the gradually observed climatic changes over the years, the increasing frequency of extreme events makes the rapid development of new plant varieties essential. Considering the fact that the world has already warmed by 1°C compared to pre-industrial levels, it can be argued that—without a reduction in greenhouse gas emissions—this value will rise sharply after 2030. The increase in temperatures, the decrease in water resources, the irregularity of rainfall and, the insufficient rainfall during critical plant growth stages, the increase in severity of droughts, the aggressive spread of diseases, and the rapid emergence of new pathotypes underscore the paramount importance of plant breeding. In order to mitigate the agricultural impacts of climate change, it is essential not only to protect agricultural lands and modernize irrigation techniques but also- and most importantly- to develop resilient plant species. In addition to developing plant species resistant to heat, drought, cold and salinity, developing plant species resistant to diseases and pests, and introducing new productive and high-quality varieties to the market are indispensable for plant breeding. This approach enables better management of agricultural inputs and water needs while promoting soil health and reclamation. In addition, with climate-compatible plant breeding studies, more effective plant production patterns are created in agricultural production systems. Ensuring food security, maintaining ecological continuity, and effectively utilizing agricultural lands are all achievable through plant breeding. The continuously advancing new technologies are effectively utilized in breeding and in solving agricultural problems, thereby allowing for the anticipation of challenges that may arise in the future.

Key words: *extreme weather events, development of new plant varieties, use of agricultural technology, sustainability, food supply security*

İklim Değişikliği Ve Bitki Islahi: Geleceğe Hazirlik

Özet

Ülkelerin gıda güvenliği bugün ve gelecekte dünya gündeminin belirleyicisi rolündedir. Gıda güvenliğinin teminatı tarım ise yaşanan iklim değişikliğinden en fazla etkilenen faaliyet alanlarının başında gelmektedir. Bu önemli çevresel sorun genel anlamda, dünya genelinde hava koşullarını, sıcaklıkları ve ekosistemleri dönüştürmekte, karasal ve denizel habitatları etkilemektedir. İklimde yavaş yavaş başlayan bu uzun vadeli değişiklikler tarım-gıda sistemlerini, gıda üretimini ve insanların geçim kaynaklarını etkileyecektir. Tüm dünyayı etkisi altına alan iklim değişikliği bitkilerin abiyotik ve biyotik stres koşullarından etkilenmesini daha görünür hale getirmektedir. İklimsel anlamda yaşanan ve yıllar bazında gözlemlenen değişimlerin aksine ekstrem olaylarda yaşanan artışlar yeni bitki çeşitlerinin hızla geliştirilmesini elzem kılmaktadır. Dünyanın sanayi öncesi döneme göre 1°C ısındığı gerçeği düşünülürse, sera gazı emilsiyonlarında azalma olmazsa 2030'dan sonra hızla bu değerin artacağından söz edilebilir. Sıcaklıkların artması, su kaynaklarının azalması, yağışların düzensizleşmesi ve bitkilerin ihtiyaç duyduğu dönemde yeterli yağış alamaması, kuraklığın her geçen gün şiddetini artırması, hastalıkların agresif bir şekilde yayılması ve yeni patotiplerinin hızla ortaya çıkması bitki ıslahının ne denli önemli olduğunu gözler önüne sermektedir. Tarımsal olarak iklim değişikliğinin etkilerinin azaltılması için tarım alanlarının korunmasının yanı sıra sulama tekniklerinin modernize edilmesi ve en önemlisi dayanıklı bitki türlerinin geliştirilmesi elzemdir. Sıcağa, kurağa, soğuğa ve tuzluluğa dayanıklı bitki türlerini geliştirmenin yanı sıra hastalık ve zararlılara dayanıklı bitki türlerini geliştirmek, verimli ve kaliteli yeni çeşitleri piyasaya sürmek bitki ıslahının vazgeçilmezidir. Bu sayede hem tarımsal girdi ve su ihtiyaçlarının yönetilmesinin sağlanması, hem de toprak sağlığı ve ıslahının gerçekleştirilmesi mümkündür. Bunların yanı sıra iklime uyumlu bitki ıslahı çalışmaları ile tarımsal üretim sistemlerinde bitki üretim desenlerinin daha etkin olarak oluşturulması sağlanmış olur. Gıda güvenliğinin teminatı, ekolojilerin devamlılığı ve tarım topraklarından efektif olarak faydalanılmasının sağlanması bitki ıslahı ile mümkündür. Her geçen gün geliştirilen yeni teknolojiler de ıslahta ve tarımsal sorunların çözümde etkin kullanılmakta ve gelecekte karşılaşılabilecek sorunlar bu sayede öngörülebilmektedir.

Anahtar kelimeler: *ekstrem hava olayları, yeni bitki çeşitlerinin geliştirilmesi, tarımsal teknolojilerin kullanımı, sürdürülebilirlik, gıda arz güvenliği*

ID: 781

Digital Agriculture

Zeynep ÜNAL[1]

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Abstract

Agriculture has been a sector of strategic importance throughout human history. Today, with the increasing population, climate change, and other global factors, the digitalization process in agriculture has accelerated. The digitalization of the agricultural sector aims to enhance the efficiency of resources and ensure environmental sustainability through the integration of digital technologies such as sensors, robotic systems, and artificial intelligence. This digital transformation will enable agricultural production to be carried out more easily within the modern living conditions that younger generations currently experience and will continue to experience in the future. In this process, interdisciplinary technologies such as the Internet of Things, sensor technologies, artificial intelligence, geographic information systems, and decision support mechanisms play a critical role in achieving data-driven sustainable agriculture. The integration of these technologies through digitalization will create opportunities to further increase the efficiency and sustainability of resources in agriculture. This study comprehensively discusses the concept of digital agriculture and the technologies related to this concept. With Agriculture 4.0, advanced technologies such as sensors, artificial intelligence, big data, unmanned aerial vehicles and land vehicles have been integrated into the agricultural sector. This integration process plays a critical role in ensuring precision and efficiency in agriculture. While precision agriculture offers an approach to local production optimization based on environmental factors, smart agriculture is characterized by the inclusion of information technologies in decision support processes. Digital agriculture is a broader framework that encompasses the management of all agricultural processes through digital platforms and the guidance of artificial intelligence-based robotic systems.

Key Words: *Agriculture, Agricultural Technologies, Agriculture 4.0, Digital Agriculture, Precision Agriculture.*

Dijital Tarım

Özet

Tarım, insanlık tarihi boyunca stratejik öneme sahip bir sektör olmuştur. Günümüzde artan nüfus, iklim değişikliği ve diğer küresel etmenlerle birlikte tarımda dijitalleşme süreci hız kazanmıştır. Tarım sektöründeki dijitalleşme süreci, sensörler, robotik sistemler ve yapay zeka gibi dijital teknolojilerin entegrasyonu yoluyla, kaynakların verimliliğini artırmayı ve çevresel sürdürülebilirliği sağlamayı hedeflemektedir. Bu dijital dönüşüm, genç nesillerin sahip olduğu ve gelecekte sahip olacağı modern yaşam koşullarında tarımsal üretimin nispeten daha kolay bir şekilde gerçekleşmesine olanak tanıyacaktır. Bu süreçte disiplinler arası teknolojiler olan nesnelerin interneti, sensör teknolojileri, yapay zekâ, coğrafi bilgi sistemleri ve karar destek mekanizmaları, veri odaklı sürdürülebilir tarımın gerçekleştirilmesinde kritik bir rol oynamaktadır. Dijitalleşmenin bu teknolojilerle entegrasyonu ile oluşturduğu fırsatlar tarımda kaynakların verimliliğini ve sürdürülebilirliğini artıracaktır.
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ID: 780

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Anahtar Kelimeler*: Yumurtacı, Yumurta verimi, Islah, Hat, Hibrit*

ID: 299

The Role of Artificial Intelligence in Increasing Milk Production on Dairy Farms

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Abstract

This research paper examines the transformative impact of artificial intelligence (AI) on dairy farming, focusing on how predictive analytics, automated milking systems (AMS), and Internet of Things (IoT) sensors optimize milk production, improve animal welfare, and enhance operational efficiency. Case studies and recent data are used to explore AI's effectiveness in addressing environmental stress factors, ensuring sustainable practices, and responding to market demands. The paper also highlights the challenges of AI adoption in dairy farming and its future potential. Artificial intelligence (AI) has introduced a transformative shift in the agricultural sector, enhancing productivity, efficiency, and sustainability. Due to the complexity of operations and the need for precise animal health management, dairy farming is among the sectors most affected by this transformation. Farmers increasingly rely on AI-powered technologies to improve milk productivity, enhance animal welfare, and ensure environmental sustainability. Predictive analytics, automated milking systems (AMS), and Internet of Things (IoT) sensors stand out as key applications in this area.This article analyzes the transformative impact of AI on dairy farming operations through case studies and recent data. It focuses on how AI optimizes production, enhances animal welfare, and improves operational efficiency. Additionally, it examines AI's effectiveness in addressing environmental stress factors, promoting sustainable agricultural practices, and responding to fluctuating market demands. In the following sections, the challenges and future potential of AI in dairy farming will also be discussed.

Key Words: *Milk, Production, Diary, Farms*

Yapay Zekanın Süt Çiftliklerinde Süt Üretimini Artırmadaki Rolü

Özet

Bu araştırma makalesi, yapay zekanın (YZ) süt çiftçiliği üzerindeki dönüştürücü etkisini incelemekte ve öngörücü analizlerin, otomatik sağım sistemlerinin (AMS) ve Nesnelerin İnterneti (IoT) sensörlerinin süt üretimini nasıl optimize ettiğine, hayvan refahını nasıl iyileştirdiğine ve operasyonel verimliliği nasıl artırdığına odaklanmaktadır. Vaka çalışmaları ve güncel veriler aracılığıyla, yapay zekanın çevresel stres faktörlerini ele alma, sürdürülebilir uygulamaları sağlama ve pazar taleplerine yanıt verme konusundaki etkinliği incelenmektedir. Makale ayrıca yapay zekanın süt çiftçiliğindeki zorluklarına ve gelecekteki potansiyeline değinilecektir. Bu makalede, yapay zekanın süt çiftçiliği operasyonları üzerindeki dönüştürücü etkisi vaka çalışmaları ve güncel veriler ışığında analiz edilmektedir. Özellikle, yapay zekanın üretim optimizasyonu, hayvan refahı ve operasyonel verimliliği nasıl artırdığı ele alınacaktır. Bunun yanında, yapay zekanın çevresel stres faktörlerine çözüm sunma, sürdürülebilir tarım uygulamalarını teşvik etme ve değişken pazar taleplerine uyum sağlama yeteneği detaylı olarak incelenecektir. Makalenin ilerleyen bölümlerinde, bu teknolojilerin kullanımında karşılaşılan zorluklar ve gelecekteki gelişim potansiyeli de değerlendirilecektir. Yapay zeka (YZ), çevresel stres, işgücü maliyetleri ve pazar talepleri gibi uzun süredir devam eden zorluklara yenilikçi çözümler sunarak süt endüstrisini dönüştürmektedir. Otomatik sağım sistemleri (AMS), öngörücü analizler ve IoT teknolojilerinin entegrasyonu sayesinde üretkenlik artar, hayvan refahı garanti altına alınır ve sürdürülebilirlik teşvik edilir. Ancak, yapay zekanın süt endüstrisindeki tüm potansiyelini ortaya çıkarabilmek için maliyetler, eğitim ve veri entegrasyonu ile ilgili zorlukların ele alınması gerekmektedir. Başarıya ulaşmak için çiftçilerin bu yeni teknolojilere uyum sağlaması ve gerekli uzmanlıkların geliştirilmesi hayati öneme sahiptir.

Anahtar Kelimeler: *Süt,Üretim,Çiftlik*

Introduction

Artificial intelligence (AI) has introduced a transformative shift in the agricultural sector, enhancing productivity, efficiency, and sustainability. Due to the complexity of operations and the need for precise animal health management, dairy farming is among the sectors most affected by this transformation. Farmers increasingly rely on AI-powered technologies to improve milk productivity, enhance animal welfare, and ensure environmental sustainability. Predictive analytics, automated milking systems (AMS), and Internet of Things (IoT) sensors stand out as key applications in this area.This article analyzes the transformative impact of AI on dairy farming operations through case studies and recent data. It focuses on how AI optimizes production, enhances animal welfare, and improves operational efficiency. Additionally, it examines AI's effectiveness in addressing environmental stress factors, promoting sustainable agricultural practices, and responding to fluctuating market demands. In the following sections, the challenges and future potential of AI in dairy farming will also be discussed. Today, dairy farms operate in a competitive and challenging environment, pressured to increase milk production while maintaining animal welfare standards and minimizing environmental impact. Climate change exacerbates these challenges by increasing the frequency of heatwaves and extreme weather events, which affect animal health and milk productivity (Cullen et al., 2020). AI offers promising solutions by using advanced algorithms to predict outcomes and optimize farm management strategies (Dairy Foods, 2024). The use of AI systems to monitor and manage livestock in real-time marks a significant shift from traditional farming methods, paving the way for greater efficiency and sustainability

The Impact of AI Applications on Dairy Farming

Production Optimization and Yield Improvement

AI technologies improve milk production efficiency by supporting decision-making through data analytics and predictive models. Automated milking systems (AMS) optimize milk yield and milking frequency while minimizing human intervention. AI-powered algorithms monitor the health and productivity of cows in real-time, allowing for individualized milking schedules. As a result, unnecessary milking or animal stress is avoided, milk quality improves, and production costs decrease.

AI-based tools analyze large datasets from multiple sources, such as animal feed intake, body weight, and environmental conditions, to predict milk yield with high accuracy. Studies have shown that predictive models based on machine learning algorithms can achieve prediction accuracy as high as 87%, helping farmers forecast and manage variations in milk yield (MDPI). In addition, AI plays a role in product innovation by analyzing consumer preferences and guiding the development of new products tailored to market demands (Dairy Foods, 2024). This data-driven approach significantly shortens product development cycles and aligns production with consumer needs.

Enhancing Animal Welfare

AI-based IoT sensors provide continuous data on cows' health and well-being. Biometrics such as body temperature, walking distance, feed intake, and milk yield help in the early detection of diseases and the identification of potential health issues. These systems also accurately detect heat periods, enhancing reproductive efficiency. This approach ensures animal health is maintained while reducing veterinary costs.

IoT sensors provide real-time data on cow health, including heart rate, temperature, and rumination patterns. These data streams are processed by AI models, enabling the early detection of health issues and minimizing production losses (Dairy Reporter, 2024). For example, monitoring calf health in real-time allows farmers to intervene promptly, reduce mortality rates, and improve long-term productivity.

The Impact of Environmental Stress

Heat stress is a critical issue in dairy farming, reducing both the quantity and quality of milk produced. AI-powered models that predict temperature-humidity indices (THI) help farmers adjust feeding and cooling strategies, minimizing the impact of extreme weather on milk production (Cullen et al., 2020). Additionally, automated climate control systems integrated with predictive algorithms optimize indoor temperatures and ventilation.

Environmental variables pose significant stress in dairy farming. Factors such as temperature and humidity can increase animal stress levels, resulting in decreased milk production. AI-powered systems analyze weather data to provide early alerts and optimize farm conditions. For example, AI-integrated climate control systems activate cooling mechanisms when temperatures rise, ensuring animal well-being.

Moreover, AI technologies optimize resource consumption and waste management processes, contributing to environmental sustainability. Algorithms that regulate feed consumption and water usage help reduce farms' carbon footprints. Thus, environmental impacts are minimized while achieving economic savings.

Adapting to Market Demands and Gaining Competitive Advantage

AI-powered analytics tools enable farmers to predict consumer demand for dairy products and respond promptly. Data obtained from digital platforms helps farms develop better marketing strategies. AI provides flexibility in production planning, enabling farmers to quickly adapt to market changes and gain a competitive edge.
AI-powered systems optimize production schedules and monitor equipment health, predicting maintenance needs to prevent downtime (Dairy Foods, 2024). An example is the AI-powered cheese yield optimization tool developed by Ever.Ag, which provides actionable insights based on real-time data to improve productivity and quality.
Ever.Ag's cheese yield optimization tool exemplifies how AI enhances efficiency in milk processing. The tool analyzes historical production data to provide real-time recommendations, improving cheese yield and reducing waste (Dairy Reporter, 2024). Similarly, SPX Flow's SmartDry System uses AI to control moisture levels during production, ensuring consistent product quality.
Research shows that farms adopting AI technologies experience significant improvements in milk yield and operational efficiency. Farms equipped with AMS reported a 30% reduction in labor costs and a 10-20% increase in efficiency (Dairy Reporter, 2024).

Challenges in the Use of AI
The integration of AI technologies into dairy farming presents several challenges. First, the installation and maintenance of these systems can be costly, posing a significant barrier for small-scale farms. Additionally, data security and privacy concerns arise with the use of AI systems. Farmers need education and technical support to use these technologies effectively. Another challenge is the potential impact of these technologies on traditional labor. AI and automation reduce the need for manual labor, potentially leading to job losses. Therefore, retraining programs are necessary to help workers adapt to new technologies and remain employed.

Performance Metrics of AI Tools in Dairy Farms
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Case Study: AI in Cheese Production Optimization
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Benefits of AI Integration

AI technologies offer numerous benefits to dairy farms, including increased productivity, improved animal welfare, and enhanced product quality. Predictive maintenance algorithms reduce downtime, while real-time monitoring systems help farmers respond quickly to potential health issues (Cullen et al., 2020). Additionally, AI-powered climate control systems protect cows from heat stress, further boosting milk yield.

Challenges and Risks
Despite its advantages, AI adoption in dairy farming comes with challenges. High initial investment costs, the need for technical expertise, and resistance from traditional farmers are significant barriers. Moreover, data privacy concerns and the complexity of integrating AI systems into existing operations must be addressed to ensure successful implementation.
The findings suggest that AI technologies, particularly predictive analytics and AMS, significantly improve milk yield and operational efficiency. IoT sensors enhance animal welfare by allowing real-time health monitoring. Farms using AI also reported a reduction in operational costs and better adaptability to environmental changes. However, the integration of these technologies requires high initial investments and workforce adaptation, as highlighted in interviews and case studies.
Furthermore, AI's ability to predict consumer demand provides farmers with a competitive edge, enabling them to align production with market needs. The challenges identified include the high costs of installation, data privacy concerns, and the potential displacement of traditional labor.

Conclusion And Recommendations

This article has explored the transformative impact of AI on dairy farming from various perspectives. AI enhances productivity by optimizing milk production, improves animal welfare, and automates operational processes. Additionally, it offers solutions to environmental stress factors, ensuring sustainability and economic benefits. However, the integration of these technologies also brings challenges.

In the future, the role of AI in dairy farming is expected to grow, enabling farms to gain a competitive edge in the global agricultural sector. It is essential to implement educational and technical support programs to ensure the effective use of these technologies, and to take steps to help the workforce adapt to new conditions. Leveraging the opportunities offered by AI effectively will be critical for both the sustainability of farms and the future of the agricultural sector.

The findings suggest that AI technologies, particularly predictive analytics and AMS, significantly improve milk yield and operational efficiency. IoT sensors enhance animal welfare by allowing real-time health monitoring. Farms using AI also reported a reduction in operational costs and better adaptability to environmental changes. However, the integration of these technologies requires high initial investments and workforce adaptation, as highlighted in interviews and case studies.

Furthermore, AI's ability to predict consumer demand provides farmers with a competitive edge, enabling them to align production with market needs. The challenges identified include the high costs of installation, data privacy concerns, and the potential displacement of traditional labor.

This study demonstrates the transformative impact of AI on dairy farming through production optimization, improved animal welfare, and enhanced operational efficiency. AI technologies provide solutions to environmental stressors, promoting sustainable farming practices while offering a competitive advantage in dynamic markets. However, challenges such as high costs, workforce adaptation, and data security must be addressed to fully realize AI's potential. Future research should focus on developing affordable AI solutions and retraining programs to support workers in adapting to this new technology landscape.

Recommendations and Future Directions

1. Virtual Assistants and AI Training Tools

The development of generative AI tools can provide virtual training and support to farm workers, reducing the learning curve for new technologies (Dairy Reporter, 2024). AI-based virtual assistants can also facilitate communication among multilingual teams, improving overall productivity.

2. Focus on Sustainability

AI can play a crucial role in promoting sustainability by optimizing resource use and reducing waste. For instance, AI-powered feed management systems can lower methane emissions, contributing to the environmental sustainability of dairy farms.

3. Areas for Future Research

Further research is needed to explore the potential of AI in developing new dairy products with enhanced nutritional properties. AI-driven innovation in functional dairy products can align production with emerging health and wellness trends, creating new market opportunities.

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The Ecological Life of Eco-Villages

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Abstract

Eco-villages are practical examples of sustainable living. These communities reduce their carbon footprint by using renewable energy and minimize environmental pollution through waste management and recycling systems. They revitalize local ecosystems by employing organic farming, permaculture, and agroforestry methods to preserve biodiversity. Socially, they foster strong social bonds and solidarity through collaborative decision-making processes and participatory governance models. Education and knowledge sharing are fundamental missions of eco-villages, and these communities serve as educational centers to disseminate sustainable living practices. Economically, they enhance resilience by promoting local production and consumption, and generate income through social enterprises. The challenges they face present opportunities for innovation and advocacy. In conclusion, eco-villages are beacons of hope in building a sustainable and harmonious world. Eco-villages represent a holistic approach to living in harmony with nature while fostering community resilience and well-being. By integrating ecological, social, and economic principles, they offer a blueprint for sustainable development that can be adapted and scaled to various contexts around the globe.One of the key aspects of eco-villages is their emphasis on self-sufficiency and local resilience. By producing their own food through organic farming and promoting local crafts and industries, they reduce dependency on external resources and contribute to the vitality of the local economy. This not only creates a more sustainable livelihood for residents but also strengthens community ties and fosters a sense of pride and identity.Furthermore, eco-villages serve as living laboratories for experimenting with alternative lifestyles and technologies. From eco-friendly building designs and renewable energy systems to innovative waste management solutions, these communities are constantly exploring new ways to minimize their environmental impact and live in harmony with the natural world.Another important aspect of eco-villages is their focus on education and knowledge sharing. Through workshops, seminars, and hands-on learning experiences, they empower residents and visitors alike to become agents of change in their own communities. By raising awareness about pressing environmental issues and offering practical solutions, they inspire individuals to adopt more sustainable practices in their daily lives.Overall, eco-villages offer a glimpse into a more sustainable and resilient future. By prioritizing the well-being of people and the planet, these communities demonstrate that another world is possible one where humans live in harmony with nature, support one another, and thrive in balance with the Earth's ecosystems.

Key Words: *Eco-village, Sustainable living, Renewable energy, Waste management, Recycling, Organic farming*

Introduction

After the Industrial Revolution, essential needs began to be mass-produced. This mode of production led to the uncontrolled transfer of all resources to factories. A random migration movement from villages to cities started to take advantage of new opportunities and accumulate wealth. This unforeseen development brought an era of wealth, abundance, and luxury for those who controlled technology. Consequently, an expensive and unsustainable lifestyle quickly became popular. The seemingly limitless use of the planet's limited resources was presented to people as a lifestyle far beyond the available means. The perception of unlimited resources eventually led to serious disruptions in sustainability within this artificial system and the inability of the natural cycle to meet the demands of the artificial system.

With industrialization, rapid urbanization caused large population movements from rural to urban areas. For the first time in 2006, the urban population surpassed the rural population, increasing the unsustainable pressure on the world. As people left their lands, new entrepreneurs seized this opportunity, employing new profit-driven agricultural techniques and driving the development of these techniques. This situation led to the emergence of hybrid seeds, produced through cross-pollination, resulting in crops that were not resistant to diseases, lacked flavor, and were deprived of nutritional value (Rose, 2014: 57).

The scientific and technological advancements of the 17th century and the Industrial Revolution fostered rational, self-interested individuals who found themselves in a competition for power and wealth. This situation reduced natural life to land and property, a vast warehouse for consumption, and a large landfill for waste. Today, many ecological and social crises are occurring, and society as a whole strives to find solutions to these crises. The eco-village movement has the potential to fill this gap.

This study evaluates eco-villages as an alternative lifestyle for a more sustainable living against the standardized and fast consumption mentality brought by globalization. In this context, the foundations of ecology and ecological thought are discussed, followed by the formation of eco-villages on these foundations and the structural characteristics of eco-village formations.

Materials and Methods

Materials

1. **Literature Sources:**
   - **Books and Articles:** Books and articles on social changes after the Industrial Revolution, ecological sustainability, and the eco-village movement.
   - **Reports and Statistics:** Reports and statistical data on rural and urban population movements, sustainability indicators, and the agricultural impacts of hybrid seeds.
   - **Case Studies:** Various examples of the eco-village movement worldwide and case studies conducted on these examples.
2. **Field Research:**
   - **Observation:** Visits to eco-villages in Turkey and around the world to observe the structural and functional characteristics of these villages.
   - **Interviews:** In-depth interviews with residents, founders, and experts of eco-villages to gather information about their operations and impact on sustainability.
   - **Surveys:** Conducting surveys among residents of eco-villages and traditional cities to measure life satisfaction, sustainable living practices, and levels of ecological awareness.
3. **Document Analysis:**
   - **Legal and Regulatory Documents:** Analysis of the founding documents, regulations, community rules, and guidelines of eco-villages.
   - **Scientific Publications:** Analysis of scientific publications on ecological thought and sustainability.

Methods

1. **Qualitative Research Methods:**
   - **Interviews:** Conducting in-depth interviews with eco-village residents, founders, and experts to provide detailed information about their operations, community dynamics, and sustainability practices.
   - **Focus Group Studies:** Holding discussions with focus groups consisting of eco-village residents about community interactions, ecological living practices, and challenges faced.
   - **Observation:** Collecting data on daily living practices and community interactions through observations made during field visits to eco-villages.
2. **Quantitative Research Methods:**
   - **Surveys:** Conducting surveys among residents of eco-villages and traditional cities to measure life satisfaction, sustainable living practices, and levels of ecological awareness. The collected data will be analyzed to evaluate the impact of eco-villages on sustainable living practices.
   - **Statistical Analysis:** Analyzing the collected survey data and statistical information to evaluate the impact of eco-villages on sustainable living practices.
3. **Literature Review:**
   - Conducting a comprehensive literature review on the topic. Theoretical frameworks will be established, and the basic principles of the eco-village movement will be detailed.
   - Analyzing the impact of social changes after the Industrial Revolution on ecological sustainability.
4. **Comparative Analysis:**
   - Comparing traditional urban life with eco-village life to highlight the advantages and disadvantages of eco-villages.
   - Comparing the impact of eco-villages on sustainable living with other alternative lifestyles.

Using these materials and methods, the impact of eco-villages on sustainable living will be thoroughly examined, and the potential of this lifestyle will be evaluated.

Theoretical Foundations Of Ecology And Ecological Thought

The concept of ecology was first introduced in 1866 by German biologist Ernst Haeckel, derived from the Greek words "oikos" (meaning house, habitat) and "logia" (meaning study or discourse). Ecology encompasses the reciprocal relationships between organisms and their surrounding world, examining in-depth the factors that form the living environment and their interactions (Güleryüz, 2013: 9).

Ecology is a science that examines how various species continue their lives in harmony with the environment, under what conditions these species meet their needs, and in what kind of environment they activate their various functions. The most distinguishing feature of this science is its holistic approach to examining the relationships between living and non-living environments (Kayır, 2003: 25). Ecology sets the boundaries of nature and redefines its agents. The meaning of life may be constructed around obeying the natural order (Şahin, 2011: 67). Nature serves as a guide, and to develop, one must listen to and carefully observe it. Seeking truth in nature as a community will open all doors (Aggarwal, 2018: 9). There are always alternatives to activities conducted within a natural order, and nature is ready to offer the necessary support as a cooperative partner when integration with it is achieved.Nature, in its own right, has a perfect balance (Fukuoka, 2018: 56). It is constantly in motion; the conditions of any given year are never exactly the same as another. Thus, rather than taking preemptive measures, it is necessary to strive to do the best with the prevailing conditions (Fukuoka, 2018: 90). Nature, like the flowers of a fruit, must be delicately preserved (Thoreau, 2018: 15). Evaluations and perspectives that consider only humans will lead to reductive and destructive outcomes. Humans are an ecological factor interacting with their living environment, and this must be remembered (Kayır, 2003: 49).

It is necessary to understand that humans have a smaller share in the web of events unfolding in nature than is often thought. When this understanding is reached, a state of universal innocence will emerge. The universe is far more than it appears, but to see this, one must actively observe the journey within the universe. Contrary to popular belief, the earth's surface is softer and more sensitive to the traces humans leave behind (Thoreau, 2018: 359-365). In essence, humans are not superior beings above nature; they are one species among many within it (Kayır, 2003: 15). It is always beneficial for humans to learn new things from nature's wisdom and flow. There is only one world, a vast field of energy. If each being or similar life forms live by thinking only of themselves, this vast field of energy will be negatively affected. One must think of the whole. Instead of destructive actions, achieving inner harmony will allow for cooperation with nature, adding to the world's richness. Life must be lived as a whole, as its meaning lies within the entirety (Findhorn Community, 2018). The secret of naturalness lies in being whole and mentally accepting this wholeness. Engaging in life activities without any distinction in a holistic perspective significantly contributes to nature's continuity.

The entire world is one family, one creation, one intelligence (Findhorn Community, 2018: 113-128). The universe comprises a whole made up of many parts, with a living structure. Being deeply aware of this situation gives people the ability to better respond to the needs of our planet and support it (Rose, 2008: 16). Today's world is both a wild and dramatic place and a ground for the awakening of new thoughts and visions. Life expresses the complex unity that takes on countless forms of endless diversity. Humans are a part of this unity (Trevelyan, 2018: 15).

The Concept Of Ecological Living

Directing desires towards the wasteful rather than the simple and plain is putting the world in a difficult situation (Fukuoka, 2018: 120). One of the fundamental assertions in Thoreau's "Walden" is that if people lived according to simple living conditions, there would be no need for modern work (Turan, 2017: 9). Every morning one wakes up is a harbinger of a simple, innocent, and joyful life like nature. A natural day passes calmly. The work one does must be heartfelt. Entertainment is not an artificial state; it is life itself. Our life is like a drama composed of many scenes (Thoreau, 2018: 101-129).

Generally, there is enough space around us, allotted by nature. Even in environments described as wild and gloomy, it is possible to encounter something of oneself. The world we live in is but a small dot in space (Thoreau, 2018: 148-152). Humanity will progress towards spiritual awareness if it abandons material ownership and personal gain planning (Fukuoka, 2018: 120). The urge to dominate nature must be overcome. Respecting nature's complex structure will bring enrichment through simplicity (Ayman, 2011: 56).

Simplicity means deliberately and willingly foregoing certain consumption habits according to our values. Learning to share resources fairly and equitably with other living beings and leading a simple life will bring health and happiness. Simplicity expresses integrating sincerely and honestly with those around us in the simplest way possible. In this case, designing by taking nature as a model is necessary. With feedback from nature, the simplest state can be found (Scott, 2011: 57-60).

The concept of simplicity is a voluntary situation, not one born of necessity. Voluntary simplicity is a path subjectively chosen by an individual. It means deciding and acting to include economic values as minimally as possible when one has the means to acquire more goods and services. Spending should be based on actual needs, not on earned income. Voluntary simplicity is not a return to the past; rather, it is a concept that shapes the future (Dudu, 2011: 10-18). When life is simplified, the complexities faced will decrease, and loneliness, poverty, and weakness will cease to be issues (Thoreau, 2018: 365).

The concept of simplicity is directly proportional to self-sufficiency. Self-sufficiency is defined as the state where the operation of something is not dependent on anything else. It brings about a balanced division of labor and an understanding of technology that can be developed and applied on a small community scale (Dudu, 2011: 19-20). The urge for contentment and simplification against the consumption appetite created by capitalism will change the consumption culture (Şahin, 2011: 66). This consciousness finds life in eco-villages.Recently, it is possible to encounter burgeoning communes in various parts of the world. They try to build their own food and social structures. Though their numbers are few, these people play a leading role in the tendency to return to nature. When one of the states of correct food, correct action, or correct awareness is realized, the others will follow (Fukuoka, 2018: 124-152). The behavior pattern of the modern consumer is determined by the preconceived notion that needs are unlimited. People have been turned into robots programmed on what, when, how, and in what way to do things (Dudu, 2011: 22-25). Ecological living experiments create an alternative to capitalism. The ecological experience should be perceived not only as something that feeds the consumer individual but as something that eliminates the consumer individual (Şahin, 2011: 63-66).

Today's media continues to constantly indoctrinate that the lifestyle we live is one of comfort and luxury. The media impose upon individuals the idea that all existing resources in the world belong to humans, who are the ultimate lords of the universe. To create new consumption habits, the perception that the economy will collapse unless existing products are consumed is created (Güleryüz, 2013: 17). This consumption and waste situation threatens the continuity of living spaces, prompting the need for ecological alternatives.

The Eco-Village Movement As A Sustainable Living Model

The fundamental feature of eco-villages is the fusion of urban and rural life. These settlements represent the post-modern settlement pattern of the age of communication and information (Ayman, 2011: 33). The International Eco-Village Network (GEN) defines an eco-village as a rural or urban settlement where social, economic, and environmental sustainability is simultaneously implemented. Thus, a social structure can be established that meets the needs of modern life, preserves natural resources, and maintains local culture and social values (GEN, 2017: 20).

An eco-village is defined as a rural or urban settlement designed by the people living in it, where ecological balance and life satisfaction are simultaneously achieved. The establishment of eco-villages is based on three main elements: ecological, social, and economic sustainability. The primary foundation of ecological sustainability is the goal of restoring a harmonious relationship between humans and nature, leading to the development of a balance-oriented ecological consciousness (Kasper, 2008: 14-17).

Historical Development Of The Eco-Village Movement

The modern eco-village movement emerged in the 1970s and 1980s, influenced by various social and environmental movements. The term "eco-village" itself was coined in the 1990s. The rise of the movement can be attributed to increasing awareness of environmental degradation, the failures of traditional urbanization and industrialization models, and a growing interest in sustainable living practices.

The eco-village movement has been influenced by various philosophical and practical frameworks, including permaculture, bioregionalism, and the principles of deep ecology. These frameworks emphasize living in harmony with the natural environment, reducing ecological footprints, and creating self-sustaining communities.The development of the eco-village movement has been marked by the establishment of various intentional communities around the world. These communities often serve as living laboratories for sustainable practices, experimenting with alternative energy sources, organic agriculture, and communal living arrangements.

Structural Characteristics Of Eco-Villages

Eco-villages are characterized by several structural features that distinguish them from conventional settlements. These features include:

1. **Ecological Design and Architecture:** Eco-villages prioritize sustainable design principles, including energy-efficient buildings, the use of local and natural materials, and designs that minimize environmental impact.
2. **Renewable Energy Sources:** Many eco-villages utilize renewable energy sources such as solar, wind, and hydro power. This reduces dependence on fossil fuels and decreases greenhouse gas emissions.
3. **Organic Agriculture and Food Production:** Eco-villages often practice organic agriculture, emphasizing biodiversity, soil health, and sustainable farming practices. This ensures a steady supply of nutritious food while maintaining ecological balance.
4. **Water Conservation and Management:** Sustainable water management practices are crucial in eco-villages. This includes rainwater harvesting, greywater recycling, and the use of composting toilets.
5. **Community Governance and Decision-Making:** Eco-villages typically employ participatory and inclusive governance structures. Decision-making processes often involve consensus or other democratic methods to ensure that all community members have a voice.

6. **Economic Sustainability:** Eco-villages strive for economic self-sufficiency through various means, such as local production and trade, cooperative businesses, and alternative economic systems like time banking.
7. **Education and Outreach:** Many eco-villages engage in educational activities, offering workshops, courses, and tours to spread knowledge about sustainable living practices. They often serve as models and inspiration for broader societal change.

Structural Characteristics Of Eco-Villages Shaped On The Basis Of Ecological Living

The concept and implementation of eco-villages are quite new. Eco-villages have been established in various parts of the world, and there is an effort to organize them globally. Eco-villages are the product of an idea that will contribute in the long term rather than the short term. This tendency can be found both within cities and as an escape from urban areas (Topbaş, 2010: 5).Eco-villages represent a way of life where human activities are carried out in harmony with and respect for nature. In 1994, the Global Ecovillage Network (GEN) was established to create a connection among all eco-villages worldwide, to develop new projects, and to enhance existing ones (İkinci, 2011: 61). GEN defines itself as a global confederation of individuals and organizations dedicated to sustainable living by coming together to share ideas, exchange technologies, and produce cultural and educational guides, programs, and newsletters, aiming to create a sustainable evolution globally. GEN strongly supports new eco-village initiatives (Dawson, 2012: 26-27), providing a global interaction platform for eco-villages.

Three regional centers have been established for GEN: GEN Europe and Africa, the Ecovillage Network of the Americas, and GEN Oceania and Asia. The primary goal of GEN is not to increase the number of eco-villages but to raise global awareness of the eco-village concept (Litfin, 2017: 26-29, 62). The core axis of GEN's development program consists of the following three points (Topbaş, 2010: 4):

1. Preparing programs to offer alternative solutions that reduce negative impacts for a higher quality of life, cleaner society, and environment.
2. Developing technologies and enterprises for sustainable projects.
3. Developing an international network for the exchange of knowledge and skills.

Six fundamental principles for eco-villages emerged from the joint efforts of groups connected to the eco-village network in 1999-2000 (Topbaş, 2010: 2-4):

- **Autonomy:** Refers to independence in economic and energy matters.
- **Coexistence:** The ability of people to live together harmoniously in a peaceful relationship network, accepting each other's differences.
- **Openness:** Being open to local residents and groups or individuals visiting the eco-village.
- **Respect:** Primarily signifies respect for nature but also includes showing an exemplary life without forcing one's thoughts and ideas on others. It involves being respectful of oneself, being inclined to reach consensus during decision-making, having the capacity to listen to other views, and possessing sincere and warm dialogue skills. Respect also plays a significant role in developing suitable models and encouraging creativity within the community.
- **Solidarity:** Involves helping those who take on new or difficult tasks, fostering active solidarity that serves as an incentive in the challenging process of achieving a good life.
- **Freedom of Personal Belief:** Recognizes that belief is personal and an experience that cannot be fully explained. Different feelings about the world should be freely lived.

Eco-villages differ from existing villages in ecological, cultural, social, and economic aspects (Topbaş, 2010: 3-4):

1. **Ecologically:** Existing villages do not have the same level of environmental sensitivity as eco-villages, being quite behind in this regard.
2. **Culturally:** Eco-villages are better at producing and developing common values and establishing good relationships among people in friendship.
3. **Socially:** Eco-villages are better in terms of sharing and solidarity.
4. **Economically:** Integration with the local economy is less common in existing villages.

Integration with the local economy is less common in existing villages. Eco-villages must demonstrate sustainable development continuously. The members of these settlements organize various activities to create or develop the village's economy. Examples of sustainable eco-village activities include tourist visits to the area, marketing ecological agricultural products, and offering various training on nature conservation and ecological living (İkinci, 2011: 63). The accumulation of carbon dioxide in the atmosphere creates human-induced global warming due to fossil fuel use, negatively affecting the health of the entire world (Featherstone, 2018: 293-294).Overpopulation in cities leads to insecure and dangerous environments. The excessive noise of the city resembles humanity's cries (Le Guin, 2019: 10-18). An ecological community requires respect for every living being in our neighborhood. The community's needs are met internally, minimizing dependence on the outside.

Turkey has exceeded its biological capacity by 59%. However, there is rapidly increasing awareness of this issue in Turkey. Ecological life-focused projects are being produced in Turkey. In 2003, the Buğday Association for Supporting Ecological Living initiated the TaTuTa (Agriculture, Tourism, Exchange) project. The goal of this project is to develop places in rural areas that grow ecological products, are nature-friendly, and are sustainable (İkinci, 2011: 64-65). Our actions liberate our thoughts (Fombelle, 2018: 61).Some organizations have emerged in Turkey to resolve the difficulties and dilemmas in eco-villages. These organizations include EKİLAT (Eco-villages Communication Network), Buğday: Association for Supporting Ecological Living, and EKOYER (Eco Settlements Network). Individuals who wish can stay in eco-villages individually or as a group. During the time spent there, visitors contribute to the continuity and development of these formations both materially and spiritually (Asımgil, 2017: 102-104).

Through the TaTuTa Project of the Buğday Association for Supporting Ecological Living, communication between groups or individuals living an ecological life is strengthened. Places are created that set an example for the healthy use of vital resources for rural populations by moving with natural cycles. Urban people are introduced to the ecological way of life. Ecological methods, experiences, and knowledge exchanges are made first-hand. Contributions are made to the protection and sustainability of soil, air, water, climate, and biodiversity (Aydın, 2012: 44). The organizations involved in this project have pioneered creating a life that does not harm the environment by utilizing the knowledge, skills, and experiences of local people and visitors (Scott, 2011: 59).Eco-villages are seen as seeds that will secure the future on the axis of sustainability (Litfin, 2017: 27). Sustainability must be conceived as a life model, primarily in food, shelter, health, education, and security (Scott, 2011: 58). To achieve sustainability and self-sufficiency, ecological, economic, and social problems must be resolved. The individuals living in the established settlement must adapt to the local environment. In this context, a settlement model planned on the local, physical, economic, environmental, social, and cultural characteristics of a place will greatly contribute to the planned settlement. Local data is collected from the surrounding area, thus creating a natural living space in harmony with the region. Eco-villages must approach with awareness of local knowledge, traditional techniques, and practices. As a result, since each region's characteristics will differ according to its cultural structure, unique eco-villages characterized differently in other regions will emerge (Asımgil, 2017: 107-108).

To end crises, we must think with universal values. We must act in proportion to local dynamics and resources. The knowledge and experience of all past cultures worldwide present an opportunity for newly created communities. Ecological settlements established in rural areas will only succeed if they involve the local population in their efforts. Much can be learned from traditional structures (Ayman, 2011: 55). The most crucial factor enabling the mental and practical transformation of sustainable living is utilizing or receiving support from cultural values and the local population in the established structure (Scott, 2011: 59).

The reason for adopting the village model in ecological settlements is the close relationship between people and resources. In the village model, farmers can more easily recognize and identify everyone from those who grind wheat to those who pollute the river. Practices that will directly affect themselves, their relatives, and neighbors result in greater care. As in any village, bad behaviors disrupt both ecological and social balance. However, social power can play a more effective role in small settlements. The goal of eco-villages is not to return entirely to the past village life but to choose the village-type settlement as the most effective way to establish livable and sustainable economies (Litfin, 2017: 112). The most productive settlement type for starting ecological life is villages, which should eventually replace the neighborhoods of noble people and become the masters of art (Thoreau, 2018: 125-126).

Excessive wealth will only feed the sense of excessive consumption. The economy is subject to an educational experience progressing with eco-villages. Eco-villages serve as laboratories for the best sustainable economy. Innovative financial transactions, investment preferences, and even new currencies can be found. The roots of ecology and economy are the same, both derived from the Greek word "oikos." Ecology involves the family-based management of natural resources without exploitation, while economy involves managing its financial criteria and resources. Therefore, resource creation, production, consumption, and waste processes must be aligned with the life cycle. For this to happen, the economic system must change. An economy based on exploitative cheap trade at the expense of other living beings and ecosystems should not be accepted.Most eco-villagers can live comfortably below the poverty line in wealthy countries. The secret is simplicity, self-sufficiency, and sharing. Every rural eco-village produces almost all its food. Urban eco-villages obtain necessary products through their relations with rural eco-villages.

Conclusion

Eco-villages represent a progressive movement toward sustainable living that emphasizes harmony with nature and community self-sufficiency. These settlements embody principles such as autonomy, coexistence, openness, respect, solidarity, and freedom of personal belief, distinguishing them from traditional villages in ecological, cultural, social, and economic aspects. Through the support and initiatives of organizations like the Global

Ecovillage Network (GEN) and local projects such as Turkey's TaTuTa, eco-villages demonstrate the practical application of sustainable development principles.

The primary goal of eco-villages is not merely to increase their numbers but to raise global awareness and promote a lifestyle that reduces environmental impact. By integrating local knowledge, traditional techniques, and modern sustainable practices, eco-villages can create a model of living those balances ecological integrity, social well-being, and economic viability. These communities function as living laboratories for sustainable economies, exploring innovative financial systems and fostering a culture of simplicity, self-sufficiency, and sharing.

In addressing global challenges such as overpopulation, resource depletion, and climate change, eco-villages offer a viable alternative to the exploitative economic models that dominate contemporary society. They provide a blueprint for creating resilient, self-sustaining communities that prioritize ecological stewardship and social cohesion. As such, eco-villages are seeds of a sustainable future, demonstrating that a harmonious and respectful coexistence with nature is not only possible but essential for the well-being of the planet and its inhabitants. Eco-villages also contribute significantly to biodiversity conservation and the revitalization of local ecosystems. By implementing organic farming, permaculture, and agroforestry, these communities enhance soil health, increase carbon sequestration, and support diverse flora and fauna. This holistic approach to land use contrasts sharply with industrial agricultural practices that often lead to soil degradation, water pollution, and loss of biodiversity.Furthermore, eco-villages promote social innovation and community resilience. They foster strong social bonds through collaborative decision-making processes and shared responsibilities. This sense of community can enhance individual well-being, reduce social isolation, and create a supportive environment for all members. The participatory governance models adopted by eco-villages, often based on consensus or sociocracy, ensure that all voices are heard, and collective wisdom is harnessed to address challenges and make decisions.Education and knowledge sharing are central to the mission of eco-villages. They often serve as educational centers, offering workshops, internships, and volunteer opportunities to spread sustainable living practices. By partnering with schools, universities, and non-governmental organizations, eco-villages extend their impact beyond their immediate boundaries, inspiring broader societal change.Economically, eco-villages are laboratories for sustainable livelihoods. They encourage local production and consumption, reducing dependence on external markets and fostering economic resilience. Many eco-villages operate social enterprises, such as organic farms, artisanal crafts, and eco-tourism, which provide income while aligning with ecological and social values.The challenges faced by eco-villages, such as securing funding, navigating legal frameworks, and integrating with the wider society, are significant. However, these challenges are also opportunities for innovation and advocacy. By demonstrating successful models of sustainable living, eco-villages can influence policy, inspire legislative changes, and encourage the mainstream adoption of sustainable practices.

In conclusion, eco-villages are more than just ecological experiments; they are beacons of hope for a sustainable future. They illustrate that it is possible to live in a way that respects and enhances the natural world while fostering vibrant, equitable, and resilient communities. As we face the pressing environmental and social challenges of our time, the lessons and practices emerging from eco-villages offer valuable guidance for building a more sustainable and harmonious world.

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ID: 301

Comparison of Technical Efficiency between Boro Rice and Maize Production in the Northern Region of Bangladesh

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Abstract

This study examines the scale and technical efficiency of Boro rice and maize cultivation in northern Bangladesh, focusing on the Dinajpur and Lalmonirhat districts. Utilizing stochastic production frontier analysis, the research assesses the key factors affecting production efficiency and resource utilization among smallholder farmers. The findings indicate that maize producers demonstrate higher technical efficiency compared to Boro rice farmers, with efficiency levels for maize often surpassing 90%. Fertilizer use is crucial in enhancing maize productivity, while labor plays a significant role in the cultivation of both crops. Additionally, younger and more experienced farmers exhibit higher efficiency, highlighting the importance of human capital in agricultural productivity. Despite these improvements, challenges remain, such as limited access to extension services, credit facilities, and quality inputs, which hinder the potential of both maize and Boro rice farmers. The study also identifies inefficiencies among Boro rice farmers, attributed to suboptimal resource utilization and a lack of adoption of productivity-boosting practices. For maize, the complementarity between labor and fertilizer use suggests opportunities for integrated resource management strategies to boost output. The findings align with previous research, emphasizing that efficiency gains can be achieved through targeted interventions, including improved access to timely services, training programs, and financial support. The insights provided are valuable for policymakers, extension agents, and stakeholders working to promote sustainable agricultural practices and improve productivity in Bangladesh's smallholder farming systems.

Key Words: *Technical Efficiency, Boro Rice Farmers, Maize Production, Stochastic Production Frontier*

ID: 302

Growth Performance of Broiler Chicken (*Gallus gallus domesticus*) in Response to Cinnamon Powder as Feed Additives

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Abstract

One hundred-twenty (120) heads of day-old Cornish-cross broiler chicks were used in the study, which employed a Completely Randomized Design (CRD). The purpose of the study was to evaluate the growth performance of broiler chickens in response to cinnamon powder supplementation. There were four treatments which were replicated three times having 10 broiler chicks per replication. Treatment 1 (T1) had 50g cinnamon powder as feed additives, Treatment (T2) with 75g cinnamon powder, Treatment 3 (T3) with 100g cinnamon powder and the Control group (T0) had a basal diet of commercial feeds with no feed additives. The study investigated the growth parameters of broiler chickens for 30 days, after the termination of the study the chickens were slaughtered and weighed to determine the carcass performance of the chickens. After the period of experimentation broiler chickens from Treatment 3 (T3) with 100 grams of cinnamon powder obtained the highest live weight compared to other treatments. Also, it was observed in the study that broiler chickens from Treatment 3 (T3) had the highest return on investment with 64%.

Key Words: *Cinnamon Powder, commercial feeds, feed additives, growth performance, Cornish-cross*

ID: 303

Knowledge Towards Food-Borne Parasitic Zoonoses and Self-Reported Hygiene Practices of Fish and Meat Vendors in the Public Market of Bay, Laguna

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Abstract

Food-borne parasitic zoonoses (FBPZs), caused by the consumption of food or water contaminated by infectious parasites, pose significant public health concerns in countries like the Philippines, where animal source foods are integral to diet and these diseases remain endemic. As they are often transmitted through food-handling practices, vendors have an important role in their prevention. With this, the study assessed the level of knowledge of the fish and meat vendors in Bay Public Market towards FBPZs and their hygiene practices. A descriptive cross-sectional study was conducted on 37 participants through the completion of a survey questionnaire on socio-demographic profile, knowledge of FBPZs, and self-reported hygiene practices. Data analyses were done through descriptive statistics, Pearson correlation, and Spearman correlation test. Results revealed that the majority (65.7%) have a good level of knowledge on FBPZs. Vendors reported that they always (median = 5) adhere to good hygiene practices and rarely (median = 2) to poor hygiene practices. Furthermore, a significant but moderate inverse correlation (r=-0.430, p=0.008) was found between vendors' age and knowledge on FBPZs. Hence, there is a need for targeted interventions to enhance understanding of FBPZs, particularly among older vendors, and to further improve hygiene practices to mitigate risk of transmission of these diseases.

Key Words: *Food-borne parasitic zoonoses, knowledge, hygiene practices, fish and meat vendors, animal source food, food-borne diseases*

Introduction

Access to an adequate supply of safe and nutritious food is essential for a sustainable life and good health. Despite this fact, many public health agencies do not completely understand the global importance of food safety. Food-borne disease (FBD) is becoming more common based on epidemiological surveillance (Käferstein & Abdussalam, 1999). According to WHO, 600 million people are reportedly becoming ill after consuming contaminated food, while 420,000 die every year. Infants, young children, the elderly, and people who are ill are particularly affected by the vicious cycle of disease and malnutrition that this creates (WHO, 2022).

Some food-borne illnesses are considered to be zoonotic. Zoonotic diseases are infectious diseases that may be transmitted from animals to humans. Unsafe farming methods, poor food handling, and contamination during production or distribution are a few of the key pathways for zoonotic illnesses to enter the food we consume (Liou, 2021). Therefore, food is an important vector for many zoonotic pathogens. However, it is important to note that food from animal sources increases the human health risk of food-borne zoonoses (Carrique-Mas & Bryant, 2013). This is because vertebrate animals are natural reservoirs for many zoonotic diseases (Leahy et al., 2022).

Food-borne zoonoses (FBZs) can be classified into three: parasites, bacteria, and viruses. Food-borne parasitic zoonoses (FBPZs) have afflicted human lives, many of which are caused by helminths. Schistosomiasis, cysticercosis, trematodiasis, and echinococcosis are prominent zoonotic parasite illnesses, and some of them have high mortality rates or long-term consequences including cancer and neurological abnormalities (Wielinga & Schlundt, 2012). An estimated 23.2 million cases and 45,927 fatalities every year have been reportedly caused by food-borne parasitic diseases (Torgerson et al., 2015).

In the Philippines, several FBPZs were documented in a study by Eduardo in 1991 and 2001. These include echinostomiasis, artyfechinostomosis, fascioliasis, heterophyiasis, carneophallosis, clonorchiasis, paragonimiasis, taeniasis, echinococcosis/ hydatidosis, diphyllobothriosis/spirometrosis and sparganosis, intestinal capillariasis, gnathostomiasis, angiostrongylosis, toxoplasmosis and sarcosporidiosis. While some of the FBPZs are now rarely observed, others remain significant concerns for public health. Many of these diseases are endemic in some regions of the Philippines, particularly where there is a tradition of eating raw or undercooked fish, snails, crustaceans, and meat (Eduardo, 1991, 2001).

A wide range of foods typically come together in markets. In Asia, public wet markets are regarded as traditional food providers and are key suppliers of everyday goods including fresh meats and produce (Carmen et al., 2020). As a source of food for human consumption, food safety is of great importance in public markets to protect consumers as well as vendors from foodborne diseases. Vendors, in particular, have significant roles in the etiology of FBZs outbreaks (Grwambi, 2020). The manner in which food is prepared and handled by vendors can cause cross-contamination and encourage the spread of FBZs. Several studies have shown how a lack of knowledge among vendors of animal-source food in low- and middle-income countries causes unsafe practices to persist (Leahy et al., 2022). Hence, understanding and improving the vendor's awareness has been a focus to address this issue. Furthermore, according to Murrell (2013), with a lack of knowledge about infection and proper hygiene, poor animal husbandry, and improper storage and disposal of human and animal waste products, the risk of people for FBPZs is at highest. This emphasizes the importance of determining vendor knowledge regarding FBPZs, especially those that handle animal source food, and their hygiene practices in their work settings. Not only are they vulnerable to the disease because of the nature of the foods that they market, but also because of their level of knowledge about these FBPZs and their compliance with hygiene practices.

This study aimed to assess the level of knowledge on FBPZs and the hygiene practices of the fish and meat vendors in the public market of Bay, Laguna. Specifically, it described the socio-demographic profile and hygienic practices of the fish and meat vendors. It also measured the level of knowledge of the fish and meat vendors about FBPZs and determined their source of knowledge about food safety. Furthermore, this study determined the relationship among the knowledge of FBPZs, hygienic practices, and socio-demographic profile of the fish and meat vendors. The findings of this study provide local data on the level of knowledge of the fish and meat vendors in the public market of Bay, Laguna regarding FBPZs and their compliance to hygiene practices. These are useful for local government units (LGUs), especially of Bay, Laguna, for developing programs, and policies, as well as for planning interventions towards improving the knowledge on FBPZs and scaling up the food safety practices of public market vendors. Such interventions are crucial to lessen the risk of consumers and vendors against food-borne diseases (FBDs) such as parasitic zoonoses and strengthen the market's competitiveness in meeting global food safety standards.

Materials and Methods

Locale of the Study

The study was conducted at the Pamilihang Bayan ng Bay or Bay Public Market, which is a central public market and biggest market of Bay located in Barangay Dila along Jose Rizal Avenue, Bay, Laguna. Bay Public Market is situated near the key municipal institutions, including the Municipal Hall and San Agustin Parish Church, public and private educational facilities, and foodservice and other business establishments. Furthermore, the public market is highly accessible to most barangays of Bay and nearby food establishments as well as nearby municipalities, making it the major source of daily food for the locals residing in the municipality and even locals from other municipalities.

Research Design

The research design selected to address the objectives of this study was a descriptive cross-sectional. A cross-sectional study design involves gathering of data on the presence or level of one or more variables of interest as they exist in a defined population at one particular time (Aggarwal & Ranganathan, 2019). Similar studies by Alemayehu and colleagues (2021) and Otuh et al. (2023) that were conducted in the past utilized the cross-sectional method of study to assess the knowledge and practice, along with other variables, of different populations of interest on FBZs. Furthermore, cross-sectional study is relatively simple and inexpensive to carry out (Aggarwal & Ranganathan, 2019). Specifically, a descriptive cross-sectional study was selected as it can provide data for describing the status of a variable or relationships among variables at a fixed point in time (Ihudiebube-Splendor & Chikeme, 2020). This study will not only describe the socio-demographic profile, the level of knowledge on FBPZs, and the hygienic practices of the vendors but also determine the relationship among these variables. Therefore, this design was found appropriate for the aims of this study.

Study Population

The study focused on the fish and meat vendors of Bay Public Market. A list of the fish and meat business lines operating with business permit and license in the Bay Public Market was obtained from the Business Permit and License Office of the Municipality of Bay. From the list, the researcher ensured that all the stalls included in the lists still existed or operated prior to the data collection period. Fish and meat stalls that were no longer operating were excluded from the list. The total population of interest consists of vendors from the 39 stalls identified as actively selling fish and meat in the Bay Public Market based from the municipal list and actual checking. All vendors from the stalls selling fish and meats were the target participants of this study. Given the small population of the study, a complete enumeration survey was conducted. A complete enumeration method or a census is a non-

sampling method that involves studying the entire population of the study (Arnab, 2017). A census is free from sampling error, providing a true measure of the population. However, it can be difficult to enumerate all units of the population within a given time, and it can cost more and may entail more time to collect and analyze data. That is why when the number of survey units in a population is so large, the units are sampled which is more practical. However, in this study, the population is not very large for a whole population survey to be impossible to carry out. For very small populations (50 or less), one needs almost the entire population to achieve accuracy (Morris, n.d.). Considering that the population in this study was only 39, a whole population survey was done.

The study intended to conduct a whole population approach, aiming to survey every stall. However, due to practical constraints, such as closures during the data collection period, 2 stalls were not included in the survey. Hence, vendors from the 37 stalls were the final participants of this study.

Data Collection

Questionnaire Design

A self-administered survey questionnaire intended to measure the knowledge towards FBPZs and the hygiene practices of the fish and meat vendors was developed as there are no questionnaires that can be adapted from other studies for this topic and the target population. The questions and the number of questions in the survey questionnaire were revised accordingly based on the comments of the panel of experts and the pre-testing carried out. The resulting 29-item questionnaire was categorized under three (3) parts. The questionnaire that was developed was also translated in the local language, which is Tagalog, to suit the characteristics of the target population and ensure that they understood the questions.

The first part of the questionnaire covers the socio-demographic characteristics of the respondents, containing basic information on the gender, age, level of education, the number of years that they have worked as vendors, their merchandise, and whether they have attended a food safety seminar.

The second part focused on the knowledge of the vendors on FBPZs, which was further subdivided into two parts. The first part contains a question on whether the vendors knew about the FBPZs. This question aims to determine the awareness of the vendors on FBPZs. To determine the source of knowledge of the vendors about FBPZs, a question on where they have heard or read about it was included. Furthermore, the respondents were asked to provide examples of FBPZs that they have read, heard, or read to confirm that they really are aware or have knowledge about the FBPZs. The second part of part two (2) also included 10 statements revolving around concepts of FBPZs with three possible responses – true, false, and do not know. The statements were developed from the report of the Food and Agriculture Organization (FAO) and World Health Organization (WHO) about the current status of knowledge on parasites and their public health impact (FAO & WHO, 2014). Furthermore, statements were also generated based on the fact sheets on different FBPZs published by the Food and Agriculture Organization (FAO), World Health Organization (WHO), and World Organisation for Animal Health (WOAH) (2021). These resources contain necessary information about the transmission and risk factors, signs and symptoms, detection and diagnosis, treatment, and control and prevention of various FBPZs. For this 10-item part, each item that was answered correctly by the respondents bears 1 point or score. Incorrect answers, including "do not know" responses were given a 0 point.

The third section covers the hygienic practices of the vendors, which contains 10 statements with five categorical answers (1-never, 2-rarely, 3-sometimes, 4-often and 5-always) to measure the extent of application of the stated practices. The statements for this section were developed from the Codex Alimentarius book of the FAO and WHO (2022), which includes the Good Hygiene Practices (GHP) that the food business operators (FBOs) must understand and follow to oversee food safety and suitability.

Validity and Reliability

To ensure validity, the questionnaire was sent to six (6) food and nutrition experts. The panel of experts was asked whether each question or statement were valid or not. The experts were also asked to provide comments to further improve the survey questionnaire. The inter-rater agreement was analyzed through Cohen's Kappa (McHugh, 2012). The survey consisted of 29 items and the computed value for Cohen's Kappa was 0.9655, which means that there is an almost perfect agreement among the answers of the expert, ensuring that the survey questionnaire was valid.

To further assess the applicability of the survey tool to the intended population, a pre-testing was carried out among fish and meat vendors in small markets and roadside stalls around Los Baños and Bay, Laguna. A total of 18 respondents took part in the pre-testing. The administered questionnaires during the pre-testing were the revised version based on the comments and suggestions of the panel of experts.

To measure the reliability, the internal consistency of the survey tool was determined using Cronbach's alpha, wherein a value of at least 0.7 guaranteed the consistency of the questionnaire (George & Mallery, 2003). In the survey questionnaire, the knowledge (part 2B) and hygiene practice (part 3) parts were subjected to Cronbach's alpha. The part 2B, which contains 10 items of true or false statements, had a computed Cronbach's alpha of 0.7414, which means that it has an acceptable internal consistency. The part 3, containing 10 items of 5-point likert

scale statements had a computed Cronbach's alpha of 0.7217, which means that it has an acceptable internal consistency as well.

Survey Conduct

The data collection was conducted from 23 May to 25 May 2024 at the wet section of Bay Public Market. The informed consent form and questionnaire were handed out personally by the researcher to the literate participants. The respondents were required to read and understand the form, and then sign them before answering the questionnaire. After answering, the researcher collected the certificate of consent and survey questionnaire from the participants and immediately gave the incentive as an appreciation to the participants. For the participants who were illiterate or were unable to read the survey tool due to poor eyesight, the researcher read the consent form and questionnaire and recorded the answer as spoken by the participants. A thumbprint in the certificate of consent was obtained from the illiterate participants who agreed to participate in this study.

Data Analysis

All the data that were collected were entered in Excel spreadsheet. Statistical coding and computation were done in the RStudio Integrated Development Environment (IDE) by a statistician.

The data were presented using descriptive statistics through frequency and percentage distribution. This analysis was used to describe the socio-demographic profile, knowledge on FBPZs, the distribution of correct and incorrect answers in the true or false statements, and the level of knowledge on FBPZs.

The level of knowledge on FBPZs was determined through the percentage of correct answers by each respondent in the part 2B of the survey questionnaire. Each statement in this part that was correctly answered by the respondents was given 1 point. The maximum score for this section was, therefore, 10 points. The cumulative score for this section was then converted to 100%, wherein interpretations were made. A score of below 70% was considered a poor level of knowledge while a score of 70% and above was considered a good level of knowledge, which was adapted from a related study on the food safety knowledge, attitude, and hygiene practices of food handlers (Tuglo et al., 2021).

For describing the hygienic practices of the vendors, the median score or answer for each statement was determined. To analyze the correlation between variables, Spearman's rank correlation and Pearson correlation tests were used (Table 1). The Pearson correlation coefficient was used to evaluate the strength and direction of the relationship between two continuous variables such as age and knowledge, and years of experience and knowledge. This correlation test has been similarly used in related studies about food safety KAP of street food vendors in Bangladesh and food handlers in Ghana (Meher et al., 2022; Tuglo et al., 2021). Pearson correlation test was also employed in a study about food safety KAP of food handlers in Indonesia which uses total population (Putri & Susanna, 2021). Spearman rank correlation, on the other hand, was used to evaluate the strength and direction of association between ordinal variables such as the level of education and hygiene practices (Schober et al., 2018). This correlation test has also been used in a study about food safety KAP of street food vendors in Bangladesh (Meher et al., 2022). To determine the significance of the identified relationship between variables, a p-value < 0.05 was considered statistically significant. Nonetheless, non-significant relationships can still be discussed (Hanover College Psychology Department, n.d.). A non-significant result does not necessarily mean that there is no relationship between variables and could be due to a small effect or low statistical power of the study (Fein et al., 2022).

Table 1. Interpretation of correlation coefficient.

Correlation Coefficient	Strength of Linear Correlation/Association
0.00 - 0.20	Very Weak
0.21 - 0.40	Weak
0.41 - 0.60	Moderate
0.61 - 0.80	Strong
0.81 - 1.00	Very Strong

Results and Discussion

Socio-Demographic Profile

The fish and meat vendors surveyed in this study were mainly female vendors (64.9%) with only 35.1% were male vendors (N=37). The youngest respondent that was surveyed was 18 years old while the oldest was 75 years old. The mean age of the respondents is around 44 years old with a standard deviation of 15.33. Hence, they are commonly around 21-65 years old. The majority (56.7%) of the vendors have attained high school level of education, including high school graduates. Some had no formal education (2.7%) and had vocational education (8.1%). Most (40.5%) of the vendors had over 10 years of working experience as fish and meat vendors (Table 2).

Table 2. Percentage distribution of the respondents according to socio-demographic characteristics, public market of Bay, Laguna.

Characteristics	Indicators	Total, n (%) n = 37
Sex	Male	13 (35.1%)
	Female	24 (64.9%)
Age group	< 21 years	2 (5.4%)
	21-35 years	12 (32.4%)
	36-50 years	11 (29.7%)
	51-65 years	10 (27.0%)
	> 65 years	2 (5.4%)
Level of Education	No formal education	1 (2.7%)
	Elementary level	2 (5.4%)
	High School level	16 (43.2 %)
	High School graduate	5 (13.5%)
	College level	6 (16.2%)
	College graduate	4 (10.8%)
	Vocational level	2 (5.4%)
	Vocational graduate	1 (2.7%)
Years of Work Experience	< 1 year	3 (8.1%)
	1-5 years	10 (27.0%)
	6-10 years	9 (24.3%)
	> 10 years	15 (40.5%)

Interestingly, many of the fish and meat vendors surveyed in this study were female, which contradicts several related studies wherein male food vendors or food handlers predominate (Jianu & Golet, 2014; Kanaan et al., 2023; Siddiky et al., 2022). The fish and meat vendors were also mostly around 21 to 65 years old, which is a wider age range than the respondents, around 21 to 50 years old and 20 to 40 years old, in related studies (Jianu & Golet, 2014; Siddiky et al., 2022). This can be due to the fact that the Philippines certainly has a wide range of working age, from 15 years old to 64 years old (PSA, 2020). The majority of the fish and meat vendors in this current study attained a high school level of education, which is comparable to the studies in western Romania and Ghana, wherein most meat handlers and street food handlers have a high school or secondary level of education (Jianu & Golet, 2014; Tuglo et al., 2021). Market vendors have often been characterized by several studies with their low level of education, especially elementary and high school levels (Adzitey et al., 2018; Amaami, et al., 2016; Khanal & Poudel, 2017; Siddiky, et al., 2022). Furthermore, most fish and meat vendors in this study have over ten years of working experience as market vendors, which was longer than the related studies wherein the majority of their food handlers or vendors have less than 5 years of work experience (Jianu & Golet, 2014; Kanaan et al., 2023; Siddiky et al., 2022).

Based on Figure 1, most of the vendors sell either fish (43.2%) or pork (40.5%), while only 21.6% sell chicken and less than 3% sell beef. Some vendors (10.8%) also sell other fish and meat products including carabao meat, shellfish like mussels and shrimps. The highest percentage of vendors selling fish could be due to the fact that the municipality is near the Laguna de Bay, where freshwater fishes are available. Furthermore, there are several local ponds in the municipality that produce tilapia and catfish (Municipality of Bay, 2022).

Majority (62.2%) of the fish and meat vendors have no experience in attending any food safety seminar. Only 37.8% of the vendors have attended seminars or training on food safety (Figure 2). This proportion was higher in a study in Bangladesh wherein none of the chicken vendors had food safety training (Siddiky et al., 2022), but somehow close to the 44% of food handlers who received a food safety training course in Ghana (Tuglo et al., 2021). The disparity could be caused by factors such as accessibility of food safety programs for vendors and varying regulations in their corresponding local governments. Nevertheless, the high proportion of vendors who never had any food safety training in this study suggests the need for the market supervisor and the LGU to prioritize training initiatives, especially given the nature of their work involving food handling. Food safety training can be given to enhance knowledge, attitude, and practices of food handlers or vendors towards food safety (Siddiky et al., 2022).

Knowledge of Food-Borne Parasitic Zoonoses

The majority (n=28, 75.7%) of the fish and meat vendors reported that they do not have knowledge of what a FBPZs is and only 24.3% (n=9) claim that they know what a FBPZs is (Figure 3). Among those who claimed to know about FBPZs, only two (2) had a sense answer in relation to the question of where they heard or knew about the FBPZs. Their answers were nutrition and health, the internet, and television. The very few responses and sources provided for this question may suggest that there are limited or inaccessible sources of information on FBPZs. In fact, there is little information on food-borne parasites that is widely available from various sources,

unlike other food-borne hazards such as bacteria and chemical residues, which is why their identity and characteristics are often confused with those of bacteria and viruses (Gajadhar, 2015). Nonetheless, the cited sources of knowledge can be used by the LGU as a medium for providing information on FBPZs.

On the other hand, only two (2) responses were also given with regards to the examples of FBPZs that the vendors know or heard, which include tapeworm and worms in fish and meat. These examples are actually parasites which may cause FBPZs but not the actual disease that is being asked. This may demonstrate uncertainty and a narrow scope of knowledge concerning the various FBPZs.

Based on the assessment of the level of knowledge of the fish and meat vendors towards FBPZs, the majority (65.7%) had a score of 70% and above, hence, they have a good level of knowledge. 34.3% of the vendors, on the other hand, displayed a poor level of knowledge regarding FBPZs (Figure 4). On average, respondents had a score of 6.57 with a standard deviation of 1.91.

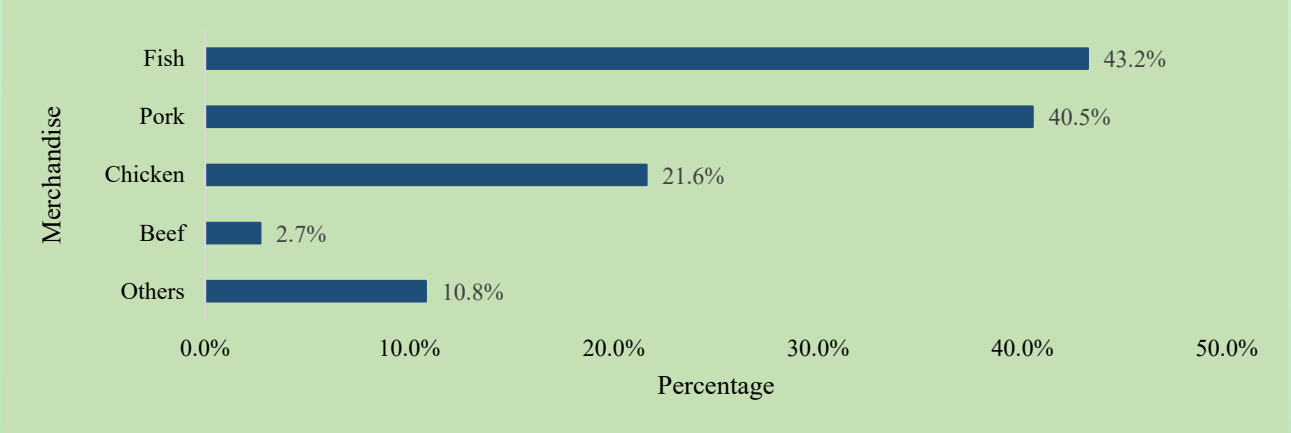


Figure 1. Percentage distribution of the fish and meat vendors' merchandise in the public market of Bay, Laguna.

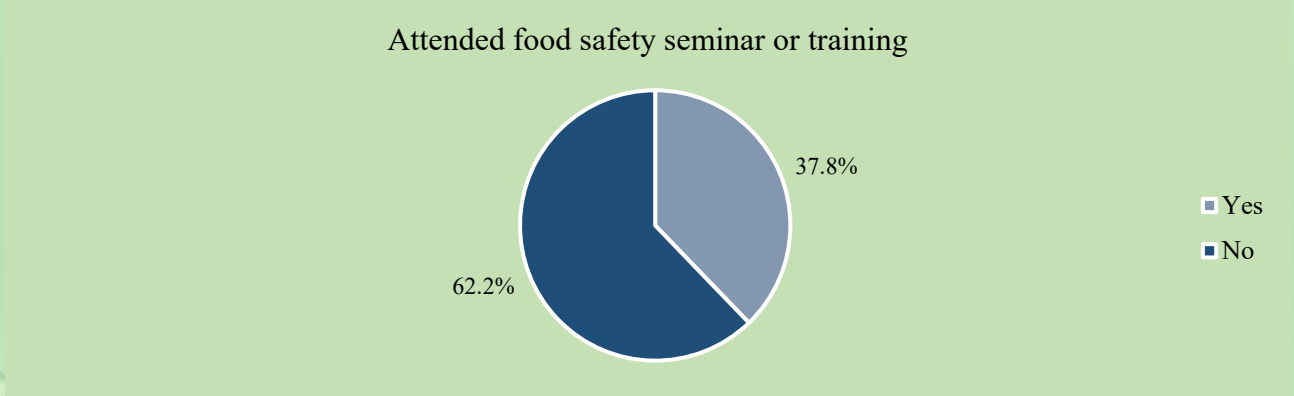


Figure 2. Percentage distribution of fish and meat vendors in the public market of Bay, Laguna who have attended food safety training or seminars.

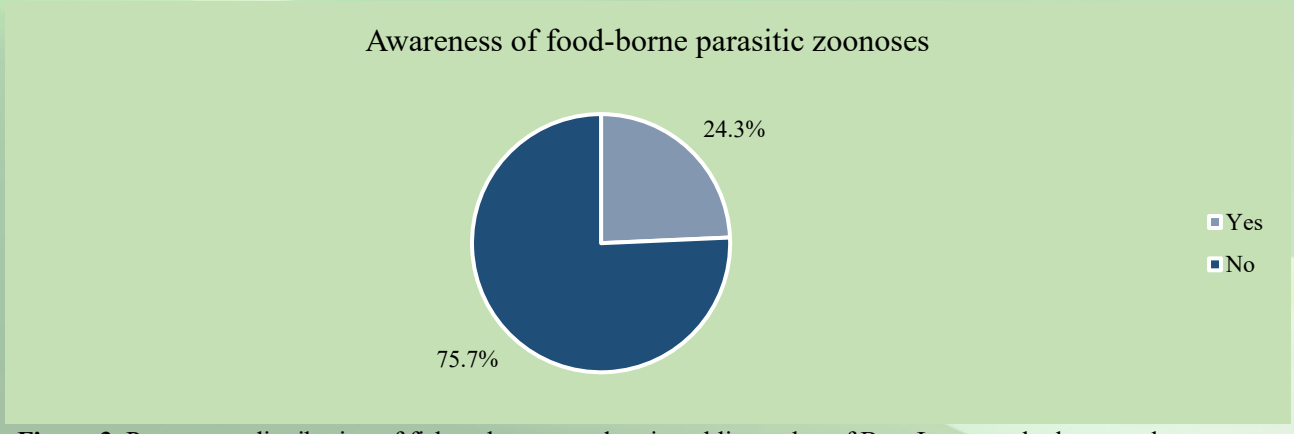


Figure 3. Percentage distribution of fish and meat vendors in public market of Bay, Laguna who knows what a food-borne parasitic zoonoses is.

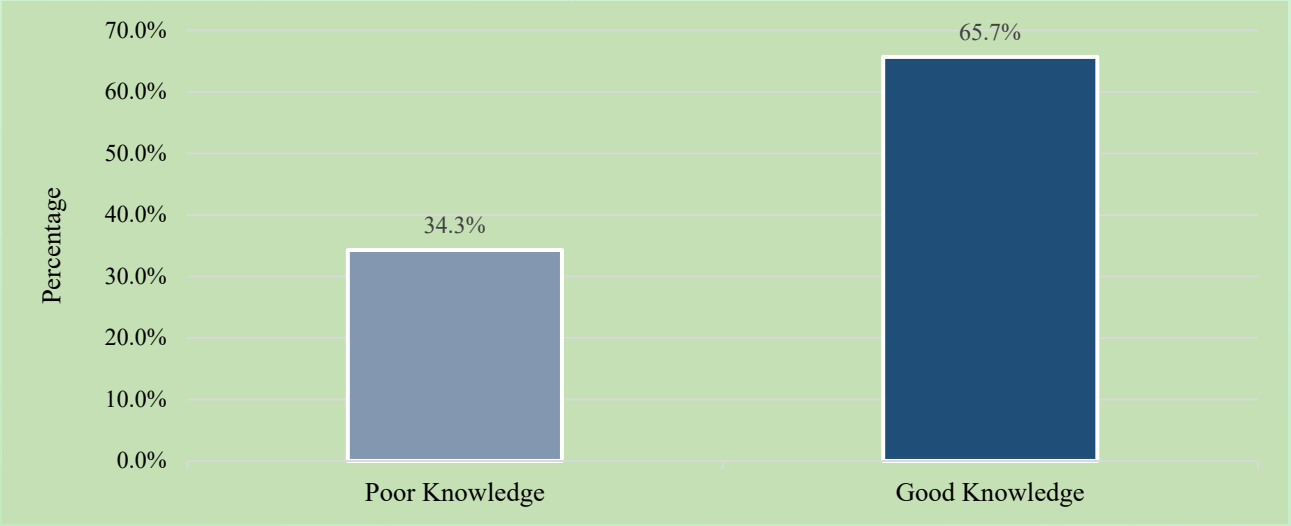


Figure 4. Level of knowledge on FBPZs of fish and meat vendors in the public market of Bay, Laguna.

Despite the low initial recognition, the surveyed fish and meat vendors may have demonstrated a good level of practical knowledge of the key concepts related to FBPZs, including transmission, associated symptoms, and preventive measures. The low proportion of vendors who were aware of what a FBPZs is, may be due to the lack of recognition of the specific term or academic terminology, which is the food-borne parasitic zoonoses. It can be that vendors possess practical knowledge about food-borne parasites but may not identify them under specific academic or technical terms. The simplicity of the examples of food-borne parasites that was also provided may be evidence for this, as tapeworms and worms are some common names. In a pilot study in Nigeria, it was found that the majority of the respondents had good knowledge of zoonoses, FBZs, preventive methods, and associated health risks, but had poor knowledge of the types of FBZs. The reason was attributed to the technical/medical nomenclature of the types of diseases in the questionnaire (Otuh et al., 2023).

The relatively good level of knowledge about FBPZs in this study may be attributed to several factors, including the years of work experience and the level of education of the fish and meat vendors. Many vendors in this study have over ten years of working experience. This extensive work experience likely gave them exposure to various aspects of food safety and the risks associated with some FBDs. According to Teferi (2022), food handlers with longer work experience may have accumulated better knowledge and skills associated with food safety. Hence, in this study, the vendors may have gained knowledge related to food safety and FBZs through observations or personal experience while working. Moreover, despite the fact that the majority of the vendors have a high school level of education, the basic education that they received may still provide them with foundational knowledge on food safety. Here in the Philippines, part of the curriculum for grade 7 or 8 is the home economics cookery course in technology and livelihood education (TLE). It includes discussion on some biological hazards or risks (DepEd, 2016b). Moreover, the health subject in grade 4 includes topics on food safety principles and food-borne diseases (DepEd, 2016a). Hence, the foundational education that the vendors have may contribute to their understanding of food safety and FBDs, despite lacking in technical terms, such as the FBPZs.

The observed good level of knowledge among vendors is encouraging from a public health perspective, as it indicates some foundational understanding of key aspects related to food safety and zoonotic diseases, especially parasitic zoonoses. Such knowledge is crucial for implementing effective hygiene practices and preventive measures to minimize the risk of foodborne illnesses, particularly FBPZs, within the market setting. A related study found that a good knowledge in the manner of transmission, prevention, and acquisition of meat-borne parasites has been directly correlated with proper food safety practices, which may lower the risks of parasitic infection (Camacho, et al., 2021). This finding of the study was inconsistent with other related studies on knowledge of food handlers specifically on zoonoses. A study on Nigeria found that the overall level of knowledge and awareness among suppliers of bushmeat was low (Ozioko et al., 2018). Similarly, a study in wet markets in Dhaka, Bangladesh found that although chicken vendors have satisfactory levels of knowledge on food safety in general, they had unsatisfactory knowledge on zoonoses and food-borne pathogens (Siddiky et al., 2022). Nonetheless, a survey in India had consistent results with this study, wherein the majority (60%) of butchers showed awareness of the commonly occurring zoonotic diseases (Prabhakar et al., 2017).

While this study found that the majority of the fish and meat vendors had a good level of knowledge regarding FBPZs, certain areas in the survey highlighted significant gaps in the understanding. Table 3 summarizes the vendors' answers about FBPZs. Most of the fish and meat vendors displayed poor knowledge on the source of some food-borne parasites as only 42.9% of them knew that lung flukes can originate from dogs and cats. Lung fluke infection, or *paragonimiasis*, is known to be endemic in eight of the 17 administrative regions in the

Philippines (WHO et al., 2020). This can originate from dogs and cats, passed on to and infect freshwater crustaceans that are foods of humans, causing diseases upon eating raw or undercooked (WHO et al., 2021). However, less than half (48.6%) of the respondents only knew the risks of FBPZs associated with consuming raw or undercooked fish and meat, highlighting a crucial gap in knowledge regarding the transmission of parasitic infections through food. This underscores the importance of knowing the source and transmission of lung fluke infection and other parasitic zoonoses among vendors for implementing appropriate preventive measures such as practicing safe food handling, towards mitigating the risks against FBPZs.

The majority of the vendors displayed poor knowledge of the proper storage temperature for preventing FBPZs, as approximately one-fourth (25.7%) knew that it is not right to store fish and meat at high temperatures to prevent diseases from food-borne parasites. This was somehow consistent with the result of a study, wherein it was found few vendors and consumers correctly indicated that protein foods, including fish and meat, should be discarded if exposed to non-refrigerated temperature for 2 hours (Nkosi & Tabit, 2021). This lack of knowledge in proper temperature handling for fish and meat could be because market settings often lack refrigeration and vendors usually display their goods on a display table and are exposed to open air (GAIN, 2020). Moreover, few (40%) of the vendors knew that directly drinking raw water or water from rivers, lakes, and springs does not prevent FBPZs, with more than half (51.4%) of the respondents displaying incorrect knowledge about this. This result of the study disagrees with studies from Iraq and Ghana, which found that most food handlers displayed good knowledge of the use of treated water for cooking and consumption (Kanaan et al., 2023; Tuglo et al., 2021). The disagreement could be because this statement was negatively structured in this study. The lack of knowledge on the correct temperature for storage and safe water to use is an issue of food safety. Hence, this emphasizes the need for training or education on safe food handling temperature and safe water consumption among the fish and meat vendors. This is important as keeping food at a safe temperature and using safe water and raw materials are included in the WHO's five keys to safer food, which, when applied, can mitigate the risk of many FBZs (GAIN, 2020).

Nonetheless, in this study, the majority of the vendors showed good knowledge on some preventive measures to minimize risk of FBPZs, as almost all (97.1%) knew about washing hands and utensils and 91.4% knew about separating raw and cooked foods. The majority also have good knowledge of the possible effects of the parasites to an individual as 88.6% knew that parasites in fish and meat can make people sick if not handled or cooked properly and that they can present several symptoms to an individual. Most (74.3%) vendors even knew food or water contaminated with pork tapeworm can cause disease in various organs.

Table 3. Distribution of the respondents' answers about knowledge on FBPZs.

Knowledge Questions	Responses, n (%)		
	Correct	Incorrect	Don't know
Meat and fish can be sources of food-borne parasitic zoonoses.	21 (60%)	1 (2.9%)	13 (37.1%)
Lung flukes that affect human lungs can originate from dogs and cats.	15 (42.9%)	4 (11.4%)	16 (45.7%)
Parasites in fish and meat can make people sick if not handled or cooked properly.	31 (88.6%)	1 (2.9%)	3 (8.6%)
Parasites present in fish and meat products can cause fever, diarrhea, nausea and vomiting, headache, body ache, and stomach pain.	31 (88.6%)	0	4 (11.4%)
Consuming raw or undercooked meat and fish does not have risks in acquiring parasitic infection.	17 (48.6%)	13 (37.1%)	5 (14.3%)
Consuming food or water contaminated with pork tapeworm may cause disease involving the brain, heart, or eyes.	26 (74.3%)	3 (8.6%)	6 (17.1%)
Storing meat and fish at high temperature helps in preventing diseases from food-borne parasites.	9 (25.7%)	23 (65.7%)	3 (8.6%)
Separating food items such as raw meat and fish from cooked items during preparation, storage, and production can lessen the risk of having diseases from food-borne parasites.	32 (91.4%)	2 (5.7%)	1 (2.9%)
Drinking water directly from rivers, lakes, and springs helps in preventing diseases from food-borne parasites.	14 (40%)	18 (51.4%)	3 (8.6%)
Washing hands and utensils used for handling fish and meat can help minimize diseases from food-borne parasites.	34 (97.1%)	0	1 (2.9%)

Self-Reported Hygiene Practices

Table 4 displays the median self-reported rating of the fish and meat vendors regarding the various statements on hygiene practices. The median scores for various practices indicate the frequency with which vendors engage in these practices.

Overall, the fish and meat vendors reported that they always (median = 5) engage in good hygiene practices but rarely (median = 2) engage in poor hygiene practices. This finding somehow agrees with the result of the study in western Romania and Ghana, wherein most of the meat handlers and street food handlers, respectively, have good hygiene practices (Jianu & Golet, 2014; Tuglo et al., 2021). Personal cleanliness during food handling including wearing clean clothes and aprons, proper hand washing, and keeping nails clean and short had a median score of 5, indicating that vendors always adhere to these practices. Similarly, the practices of using safe water for washing utensils and keeping waste containers covered received a median score of 5, which means that the fish and meat vendors always adhere to these hygiene practices. These findings were comparable to a study in Ecuador wherein most street food vendors reported that they always wear appropriate and clean clothes, keep their nails short and clean, use potable water to wash utensils and raw materials, and keep a covered waste container (Rosales et al., 2023). Studies among street food vendors and chicken vendors showed that the majority of them wash their hands before and after processing and handling foods and dressing chicken, respectively (Hossen et al., 2021; Siddiky et al., 2022). Furthermore, the vendors also reported that they never (median = 1) sneeze and cough over food nor handle food products when sick, which corresponds with the answer of most the meat handlers and street food vendors surveyed in Romania and Ecuador, respectively (Jianu & Golet, 2014; Rosales et al., 2023).

While there is strong adherence in personal hygiene and cleanliness and waste management, there are practices that hold opportunities for improvements. The fish and meat vendors reported that they rarely (median = 2) wear jewelry and carry a cellphone while selling food, and handle food products after touching money. This finding disagrees with the result of a survey in Ecuador, wherein most street food vendors claimed to never wear jewelry during their work, but agrees with their result that only few vendors always practice not handling money and food simultaneously (Rosales et al., 2023). This may be because, in many food service locations, including a public market, food workers simultaneously handle money and prepare food, hence, handwashing is often neglected between these two separate tasks (Michaels, 2002). Although the handling practices mentioned were rarely done by the fish and meat vendors in this study, these practices still need to be improved as they can promote cross-contamination. In order to improve the current hygiene practice of the fish and meat vendors, the LGU should impose safety policies and provide them with proper training on food safety and hygiene practices. Proper food safety practices are important as they may lower the risks of parasitic infection (Camacho et al., 2021).

Table 4. Median rating of the hygiene practices of the fish and meat vendors.

Good Hygiene Practices			Poor Hygiene Practices		
Statement	Median	Interpretation	Statement	Median	Interpretation
Wear clean clothes and an apron.	5	Always	Wears jewelry while selling food.	2	Rarely
Wash hands with soap and water before and after handling food products.	5	Always	Carries cellphone while selling food.	2	Rarely
Keep nails clean and short.	5	Always	Handles food products after touching money.	2	Rarely
Use safe water for washing utensils used for food products.	5	Always	Sneeze and cough over food products.	1	Never
Waste containers are kept covered.	5	Always	Handles food products when sick.	1	Never
Overall	5	Always	Overall	2	Rarely

Figure 5 depicts some observations on the hygiene practices of the fish and meat vendors in Bay Public Market. One observation was that while the vendor was wearing an apron, the clothing of the vendor, which includes sleeveless shirt, shorts, and slip-on footwear, was inappropriate for their work, especially since they handle food products. This contradicts with the vendors' reported practice of always wearing clean clothes and aprons. Figure 5 also shows the exchange of money and food products between the customer and the vendor. During this activity, it was observed that the vendor did not wash hands before and after handling food products nor after handling money, which does not agree with the reported practice. Additionally, it can be observed in figure 8 that there are buckets with drippings of animal blood on its surface, which the vendors used to store water for washing equipment and hands. Notably, there were no dedicated handwashing facilities in the public market, and only faucets were available nearby (Figure 6). This observation does not support vendors' reported practice of always washing their hands and using safe water for washing utensils. According to Chapter 5, Section 24 of the municipal ordinance

mandating the laboratory test requirements in securing health cards for food handlers and non-food handlers in different establishments in the Municipality of Bay, wash hand basins shall be installed in convenient places in all food establishments, food manufacturing establishments, and public and private markets equipped with adequate supply of water and, in proper cases, with soap, cloth or paper towels and/or hand drying equipment. The absence of proper hand washing facilities at the market indicates non-compliance with this requirement.



Figure 5. Observed hygiene practices of fish and meat vendors in Bay Public Market

Figure 5 also depicts the lack of proper waste containers, with vendors using only plastic bags and sacks for waste disposal. Disposed wastes are therefore exposed to the market environment, which does not align with vendors' reported practice of always keeping waste containers closed. Figure 9 shows an overflowing garbage container near the fish and meat section, creating unhygienic conditions that could harbor pathogens. The abovementioned ordinance specifies in chapter 7, section 32 that refuse should be separated to recyclable, non-recyclable and food materials. Section 33 states that all marketplaces shall have holding bins or refuse storage area containers maintained to be vermin and rodent proof, and that individual stalls in public and private markets shall provide garbage plastic bags for their refuse. This explains why the fish and meat stalls only have plastic bags or sacks for their wastes. However, based on figure 5, stalls seem to have only one garbage bag which may not support waste segregation as ordained by the municipality. Moreover, the overflowing garbage container in figure 6 may indicate failure to maintain a vermin or rodent proof refuse storage container.



Figure 6. Hygiene observations in Bay Public Market

Aside from the mentioned sanitary requirements, section 19 of the ordinance enumerated required proper hygiene practices for food establishment personnel in processing food, including wearing of clean working garments, hairnets, caps, and apron, especially for cooks; observing good personal hygiene; proper hand washing; not allowing food handlers with long fingernails and active skin infection to work; and avoiding wearing pieces of jewelry during work duty. While ordinance for proper hygiene practice exists, it must be implemented properly, strictly, and consistently, to improve adherence among vendors. Especially in the public market, the municipality must take proactive measures, such as placing convenient hand washing facilities and having proper refuse containers, and improving or strengthening ordinances, to facilitate good hygiene practices among vendors.

Correlation between Knowledge, Hygiene Practices, and Socio-demographic Profile

Based on the correlation analysis detailed in Table 5, only age and knowledge have a significant correlation with each other. With a Pearson correlation coefficient of -0.430 and a p-value of 0.008, age has a significantly moderate inverse linear relationship with the knowledge scores of the vendors. This indicates that younger vendors tend to have higher knowledge regarding FBPZs than older vendors. This was comparable in a study in China, wherein younger vendors and consumers, particularly of age group of 26 to 35 years old had higher levels of knowledge towards food safety (Ma et al., 2019). However, the result of this current study was inconsistent with a study in Ghana which found no significant association between age and knowledge of vendors (Tuglo et al., 2021). Nonetheless, the findings of this suggest that younger vendors may benefit from more recent educational opportunities or greater exposure to information through online channels or internet, which are critical in enhancing their understanding of food safety practices, especially on FBPZs. In fact, statistics show substantial online users among younger demographics worldwide (Petrosyan, 2024). Further, a study in Indonesia demonstrated that individuals exposed to food safety information through educational institutions and social media had 2.3 times and 1.6 times higher likelihood of possessing good food safety knowledge when dining out, respectively (Nurhidayati et al., 2022). Internet and social media even ranked 1st and 2nd, respectively, as information sources about food safety and food-borne illness during a crisis (Abdulsalam & Bakarman, 2021).

In contrast, the inverse correlation between education level and knowledge scores was very weak and not statistically significant ($r = -0.107$, $p = 0.529$). This suggests that while formal education is important, it does not solely determine the level of understanding of the vendors on FBPZs. This finding agrees with a previous study indicating that other factors such as being a registered food handler, significantly impact the food safety knowledge beyond formal education (Tuglo et al., 2021).

Regarding years of working experience, a weak positive linear relationship with knowledge scores was observed, although it did not reach statistical significance ($r = 0.301$, $p = 0.07$). This indicates that fish and meat vendors with more vending experience tend to have slightly higher levels of knowledge on FBPZs, although not statistically significant. Vendors with more years of experience may have encountered various circumstances related to food safety and parasitic zoonoses, gaining related knowledge over the years. In this study, the majority of the vendors had more than ten years of working experience and had a good level of knowledge. Food handlers with longer experience may have acquired better knowledge and skills concerning food safety in their years of working (Teferi, 2022). In fact, a study found that vendors with longer working experience have significantly higher levels of food safety knowledge (Siddiky et al., 2022). In this study, this correlation did not reach statistical significance, which could mean that other factors beyond the years as a vendor may influence the vendor's understanding of FBPZs more. Nonetheless, this suggests that fish and meat vendors, despite their years of working experience, need exposure to information on FBPZs to shape their knowledge in this matter.

Similarly, attendance to food safety seminars or training showed a very weak positive correlation with knowledge scores, but this relationship was not statistically significant ($r = 0.137$, $p = 0.418$). This indicates that participating in seminars related to food safety may not substantially increase the knowledge levels of the fish and meat vendors, especially on FBPZs. This finding aligns with the studies in Nigeria and Ghana, which did not find a significant correlation and effect of receiving food safety training with knowledge of vendors or food handlers (Madaki & Bavorova, 2019; Tuglo et al., 2021). Other factors, including the quality of food safety training received, the retention of knowledge learned from the training or seminar, the relevance of the information provided, and others, may have influenced the knowledge of the vendors.

In terms of hygiene practices, the study found a weak positive linear relationship with education level, which was not statistically significant ($r = 0.269$, $p = 0.108$). This suggests that vendors with higher education levels tend to report slightly better hygiene practices, although not statistically significant. In other studies, a significant relationship was found between these variables (Siddiky et al., 2022; Tuglo et al., 2021). A higher level of education gets better knowledge, which affects their attitude and consequently reflects in their hygiene practice (Tuglo et al., 2021). However, the result of this study suggests that hygiene practices may be influenced by other factors beyond formal education. Nonetheless, a study in Ghana revealed that food safety practices of food handlers remain an issue in many nations, regardless of their educational background (Akabanda et al., 2017).

Moreover, the vendor's years of working experience showed a weak inverse linear relationship with their reported hygiene practices, but also did not reach statistical significance (r = -0.283, p = 0.09). This suggests that vendors with more working experience tend to report lower adherence to hygiene practices, although not statistically significant. This finding was inconsistent with a study in Bangladesh, wherein chicken vendors with longer working experience exhibit significantly higher practices (Siddiky et al. 2022). In contrast, a study in Ghana found no significant association between these variables, which somehow supports this current study (Tuglo et al., 2021). The disparity could be caused by differences in study population and size. However, the inverse correlation between the variables found in this study may indicate that vendors with longer experience may have become satisfied with their practice over time, feeling less important to maintain standards of hygiene practices. Therefore, LGU must be consistent and strict in implementing hygiene standards in the market that must be followed by the vendors.

Additionally, attendance to food safety seminars and reported hygiene practices of the vendors have an inverse linear correlation that is very weak and not statistically significant (r = -0.017, p = 0.919). The correlation coefficient is very close to zero, which means that there is almost no correlation between these two variables. This disagrees with a study in Ghana which significantly found that food handlers who have undergone training courses focused on food safety are more likely to exhibit good practices in food safety and hygiene (Tuglo et al., 2021). This disparity could be a result of the difference of the food safety training received and the research population. Nonetheless, food safety training in vendors is important in improving their practice as well as their knowledge and attitudes to prevent the spread and contamination of food-borne pathogens in their working environment (Siddiky, et al., 2022). While food safety training is aimed at improving the hygienic practices of the vendors, this study found near to no correlation between these variables. Therefore, LGUs should focus on providing the fish and meat vendors with food safety training that will translate into good hygiene practices.

Lastly, knowledge scores and hygiene practices of the vendors have a positive linear relationship that is also very weak and not statistically significant (r = 0.066, p = 0.699). The correlation coefficient of these two variables is also very close to zero, indicating almost no correlation between them. This is supported by two studies in Ghana and a study in Malaysia which found no significant relationship between knowledge and hygiene performance among food vendors or handlers (Amegah et al., 2020; Sani & Siow, 2014; Tuglo et al., 2021). However, several studies also suggest that a good level of knowledge on food safety translates to good hygiene practices (Siddiky, et al., 2022; Teferi, 2022). However, the result of this study may indicate that good knowledge does not always affect hygiene practices. Therefore, regardless of the level of knowledge of the fish and meat vendors, the LGUs need to encourage them to adhere to good hygiene practices as a preventive measure against FBPZs.

Table 5. Correlation matrix of knowledge of FBPZs, hygiene practices, and socio-demographic characteristics of the fish and meat vendors of the public market of Bay, Laguna.

Variables	Knowledge of FBPZs		Hygiene Practices	
	Correlation Coefficient	*p-value*	Correlation Coefficient	*p-value*
Sex	0.114	*0.502*	-0.003	*0.985*
Age	-0.43*	*0.008*	0.008	*0.962*
Education Level	-0.107	*0.529*	0.269	*0.108*
Years of Working Experience	0.301	*0.07*	-0.283	*0.09*
Food Safety Seminar or Training	0.137	*0.418*	-0.017	*0.919*
Knowledge of FBPZs	—	—	0.066	*0.699*

*Correlation coefficient is significant (p-value < 0.05).

Conclusion

This study demonstrated that the majority of the fish and meat vendors have a good level of knowledge regarding FBPZs. However, only a few vendors were familiar with the FBPZs, which may demonstrate practical knowledge about it, but may have a lack of understanding of academic or technical terms. Furthermore, gaps in understanding about FBPZs were identified including source and transmission routes of parasitic zoonoses, safe food handling temperature, and the use of safe water for prevention. The study also revealed that the fish and meat vendors have strong adherence to hygiene practices as they always adhere to good hygiene practices and rarely to poor hygiene practices. However, practices including handling cellphones and money and wearing pieces of jewelry while handling food simultaneously can still be improved. Interestingly, this study found that younger vendors tend to have higher knowledge of FBPZs than older vendors, which may be caused by the greater exposure of younger individuals to information through the internet. This medium is even one of the sources of information on FBPZs that were cited by the vendors along with television and nutrition and health. While this provides an idea of possible

mediums to use for the dissemination of information, this also reveals the limited or inaccessible sources of information about FBPZs. This highlights the importance of widely disseminating information on FBPZs as well as proper hygiene practices through various communication channels including posters, leaflets, digital platforms, and television, ensuring that it can be accessible to all vendors, especially older vendors. This will be a collective effort of the LGU, Municipal Nutrition Action Office (MNAO), and Municipal Health Office (MHO). They could also initiate targeted educational and training programs for the fish and meat vendors, which cover identification of zoonotic parasites and their transmission routes, symptoms of FBPZs, preventive measures, and demonstrations on proper hygiene practices. The LGU should also take necessary steps to implement suitable food and personal hygiene policies or ordinances that must be followed by the market vendors to increase their adherence towards good food handling practices. These efforts aim to provide awareness towards FBPZs and prevent or mitigate risks against them.

This study is the first study to investigate fish and meat vendors' knowledge of FBPZs and their hygiene practices. Therefore, further studies still need to be conducted to fill the gaps in this area. Future research could explore a broader range of markets and vendors across different places to provide a more comprehensive understanding of their FBPZs knowledge and practices. Future research could also evaluate the effectiveness of various interventions in improving vendors' knowledge of FBPZs and hygiene practices. Lastly, for future studies adopting the methods of this research, it is recommended for the researcher to observe and rate hygiene practices rather than have them rated by the vendors themselves to reduce response bias due to social desirability. This may also provide more accurate results.

Declarations

Author Contribution Statement

Mary Angelar De Miguel: data collection, data analysis, constructing the questionnaire, writing the manuscript
Aimee Sheree Barrion: supervision, conceptualization, constructing the questionnaire, expert validation, review, refine, and proofread the manuscript

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Conflict of Interest

The authors declare no conflict of interest.

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Bibliometric analysis of studies on different factors affecting egg quality

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Abstract

This study is a bibliometric analysis using the keywords “egg quality”, “eggs”, “shell” and “laying hens” as part of the analysis of factors affecting egg quality using the bibliometric library R version 4.4.2 and the software VOSviewer version 1.6.20. This study considered 626 articles in the Scopus database from January 2014 to November 2024. China stood out for its publications in the field of egg quality. In terms of international collaboration, China was also the country with the most international collaborations. The study entitled “Productive performance, eggshell quality, and eggshell ultrastructure of laying hens fed diets supplemented with organic trace minerals”, initiated by Stefanello and other researchers in 2014 and published in the journal Poultry Science was the most cited. Poultry Science stands out as the journal with the most publications related to the keywords “egg quality”, “eggs”, “shell” and “laying hens”. This study also reveals that the most productive university in the field of egg quality is also a Chinese university called “Sichuan Agricultural University”. The researcher whose research and publications have attracted the most attention also comes from China and is known as “Wang J”. In this study, the most frequently used keywords are “egg quality”, “laying hens” and “laying hen”. The main trends show that research in the field of egg quality is growing steadily and provide clearer or less clearer directions for future research.

Key Words: *egg quality, eggs, shell, laying hens, Biblioshiny,VOSviewer, bibliometric analysis*

Introduction

Thanks to the various genetic manipulations and selections carried out over the last few decades on different breeds of laying hen, today a laying hen can produce an average of 300 eggs a year under ideal rearing conditions. However, to guarantee quality eggs for consumers, several factors need to be kept under control. The clarification of certain key words would undoubtedly lead to a better understanding of the themes mentioned in this study.

Egg quality is defined as the characteristics of an egg that affect consumer acceptability (Abebe et al., 2023). Egg quality refers to various standards that define both external and internal quality. Internal quality focuses on yolk height and color, albumin viscosity and Haugh unit. External quality, on the other hand, refers to shell thickness, egg width, egg height and cleanliness(Coutts & Wilson, 2007). All egg quality characteristics are affected by several factors, including hen age and genotype, nutrition, type of rearing system and time of laying (Yang et al., 2014).

According to (Belitz et al., 2009), eggs have been a human food since ancient times. They are one of nature's most perfect protein foods and contain other high-quality nutrients. Eggs are easily digested and can provide a significant proportion of the nutrients needed daily for growth and maintenance of body tissues. They are used in many ways, both in the food industry and in the home. Chicken eggs are the most important. Those of other birds (geese, ducks, plovers, gulls, quails) are of lesser importance. Thus, the term “eggs”, without prefix, generally refers to chicken eggs.

According to (Nys et al., 2011), the eggshell is a perfectly defined structure, adapted to the various functions essential for ensuring the reproduction of birds in an external environment. Its first role is to protect the egg's contents from the physical and microbial environment, the second is to allow water and gas exchange through pores to ensure the embryo's ectopic development, and the third is to supply calcium for the embryo's bone calcification. It is strong enough to provide protection against predators during embryonic development but will become fragile enough to allow the chick to hatch.

Laying hens are sexually mature female birds of the species Gallus gallusdomesticus raised for the commercial production of eggs for human consumption. Breeding hens are not included. However, laying hens still retain some of the biological characteristics of birds, such as the habit of foraging and constant movement, fine hearing, acute daytime vision, neurotic characteristics, the use of a wide range of feeds by eating gravel to crush it (Thiruvenkadan et al., 2010).

Bibliometric analysis has been described as a scientific methodology that uses computer-assisted review to examine all publications on a specific topic or field to identify primary research, subject authors and their relationships over a given time(Nicolaisen, 2010; F.-H. Liu et al., 2022). Bibliometrics is increasingly important in managing the growing number of academic publications, which often involve empirical contributions producing voluminous, fragmented and controversial research results(Aria & Cuccurullo, 2017). Compared to other scientific review techniques, bibliometrics provides highly objective and reliable analyses because it uses a "systematic, transparent and reproducible review process based on the statistical measurement of science, scientists or scientific activity" (Wallin, 2005).

Importance and objective of study

Eggs are an important food in the human diet due to their high protein content, easy preparation and wide availability on the market, as well as their low price compared to other animal protein sources such as meat and milk(Mendoza Rodríguez et al., 2016). The poultry industry is one of the fastest-growing animal industries over time. Global egg production reached 68.26 Mt in 2013, up 94.6% from 35.07 Mt in 1990 (FAOSTAT, 2015). Over the past decade, global table egg production has risen by 24.4%, taking output to 76.7 Mt in 2018, a production that is set to increase further due to strong demand for animal-derived protein (FAOSTAT, 2021).

Given its high protein content, low levels of saturated fatty acids and rich micronutrient content, particularly in vitamins and certain minerals, it is important for consumers to have quality eggs at their disposal. It is with this in mind that, for food safety reasons, the debate on egg quality has become a hot topic worldwide in recent years. In view of the high demand for eggs on the consumer market and the ensuing overproduction, a great deal of research has been undertaken to identify the factors that can affect egg quality. From these various studies, it appears that there are indeed factors that have the capacity to act by decreasing or increasing egg quality (Abrahamsson&Tauson, 1998; Safaa et al., 2008; Pérez-Bonilla et al., 2012; Jones et al., 2014; Yang et al., 2014). Numerous other studies have been carried out to investigate the factors affecting egg quality(Barbosa Filho et al., 2006; Zita et al., 2009; Tůmová&Gous, 2012; Hanusova et al., 2015; Yenice et al., 2016; Philippe et al., 2020).

From these various studies, age, type of rearing system, breed, feed, environmental conditions, temperature... are all factors that can affect egg quality. It is therefore clear that a fair amount of scientific information has been generated on egg quality. However, to the best of our knowledge, no bibliometric study exists at the present time that has exhaustively and comprehensively examined the available literature to prompt further research in this field. Bibliometric analysis is research carried out by systematically examining articles in scientific literature on a given subject and their various characteristics to understand the trends, popularity and level of progress of the subject.

This analysis usually covers large datasets and relies on data from scientific databases (Demir, Chatterjee, &Pamucar, 2024). Thus, with the ever-increasing number of research reports on egg quality in poultry production, it proved essential to provide evidence-based information through a bibliometric analysis of research productivity by authors, countries, keywords, funding agencies and collaborative networks. The results of this study would help to outline the progress of egg quality research in poultry and its development over recent decades. It would also provide organized information for researchers and poultry industry experts and help advance research in this field.

Research questions

Each study is conducted with the aim of answering a certain number of questions. Thus, to carry out this research on the bibliometric analysis of studies on the various factors affecting egg quality, various questions were asked. These included

- Q1: What is the growth trend and citation status of articles on factors affecting egg quality?
- Q2: Who are the most cited authors in the field?
- Q3: What are the most cited journals, documents, countries and organizations?
- Q4: What are the main points of research and thematic research in this field?
- Q5: What is the most cited publication?

This document is organized as follows. Chapter 2 provides a brief overview of the literature review relevant to the theme of our study. Chapter 3 describes the research methodology. Chapter 4 provides an analysis of the research results. Chapter 5 provides a general discussion of all the results, and the final chapter presents the conclusion.

Contribution of the study

The bibliometric analysis of factors affecting egg quality will provide important data on factors affecting hen egg quality in terms of the most influential authors, the most influential sources, the most influential countries, the most influential studies in the existing literature and the most influential links. Similarly, this study will help provide an overview of previous and current research and help identify future research directions on this topic. In addition, beyond the existing literature, this study will stimulate a much deeper discussion that will lead to a better understanding of the factors affecting egg quality. This study will also enable professionals, educators and students alike to acquire in-depth knowledge of the factors influencing egg quality in laying hens, which will undoubtedly

enrich their future work. At the same time, this in-depth examination could also highlight the various gaps existing in literature, and thus provide a better orientation for future research. Finally, this study will highlight areas of research that require further attention to provide theoretical and practical implications.

Research limitations

Despite the novelty of this study and the various results it has produced, it is essential to emphasize that this work is indeed full of shortcomings:

- The documents collected as part of this study came exclusively from the Scopus database, and did not include documents from databases such as Web of Science, PubMed, Dimensions and Cochrane Library...
- The documents collected after the search do not necessarily contain all the literature related to the diversity of keywords. However, the detailed search technique used, the advanced search strategies and the logical use of Boolean operators improved the relevance and accuracy of the results obtained.
- The key term in this search, "egg quality", was combined with other keywords using only "AND" as the Boolean operator. The combined use of the Boolean operators "AND" and "OR" might have provided access to more studies. Also, the limitation of subjects to laying hens could be at the root of such a result. The use of the term "poultry" in the searches might have allowed even greater comprehensiveness of the results obtained.

Literature review

Bibliometric analysis has become an indispensable tool in academic research and scientific evaluation. It enables us to examine the complex network of scientific literature in each field of study, revealing important patterns, trends and influences(Demir, Chatterjee, Zakeri, et al., 2024). The last two decades have been marked by a rapid increase in the number of academic publications, enabling students and researchers to have a well-supported database in terms of literature reviews. According to (Rousseau, 2012) literature review helps us play an important role in effectively using a combination of previous research findings to develop research pathways and create action-based insights to implement and preserve professional judgment and expertise.

However, literature review in its traditional, narrative form is not generalizable, as it focuses on the researcher's individual experience and knowledge whereas the insights of bibliometric analyses could be generalized from the micro to the macro level (Y. Chen et al., 2019; C. Wang et al., 2020). This type of systematic literature review is designed with the aim of achieving a higher level of comprehensiveness and transparency(Cornish, 2015).

According to (Crane, 1972), bibliometrics provides more objective and reliable analyses than other techniques. The sheer volume of new information, conceptual developments and data means that bibliometrics can be used to provide a structured analysis of large amounts of information, deduce trends over time, explore themes, identify changes across disciplinary boundaries, identify the most productive researchers, journals, universities, countries and provide an overview of current research.

Regarding the literature review in this study, it should be noted that there has been no bibliometric analysis that presents an overview of the factors affecting egg quality. This study is therefore the first bibliometric analysis to present the factors affecting egg quality. Nevertheless, there are two studies that have presented in isolation a bibliometric analysis of specific factors that can affect egg quality in laying hens. Table 1 summarizes the literature review.

Table 1. Review of bibliometric analyses specific to factors affecting egg quality

Authors	Year	Keywords	Timeframe	NAR	Database	Software
Uyanga et al.	2023	Chickens, growth performance, heat stress, oxidative stress	2000-2021	468	Web of Science Core Collection	Biblioshiny and VOSviewer
Susilo et al.	2024	Animal welfare, cage-free, housing system, Laying hens, Research trend	1960 -2023	900	Scopus	Biblioshiny
This study	2024	Egg quality, egg, shell, laying hens	2014 -2014	626	Scopus	Biblioshiny and VOSviewer

NAR: Number of articles reviewed

Materials and methods

The bibliometric analysis of this subject involved several stages, as shown in figure 1. The first step in the bibliometric analysis involved selecting a database. Scopus was chosen because it is a comprehensive, multidisciplinary database covering a wide range of scientific journals, conference proceedings, books and other scientific publications. Likewise, Scopus has robust data validation procedures that guarantee the accuracy and completeness of bibliographic information, making it a reliable source for bibliometric analysis(Martín-Martín et al., 2018). To obtain the final data to be used, a process was set up. This process is presented in Table 2. 626 documents were compiled according to inclusion and exclusion criteria.

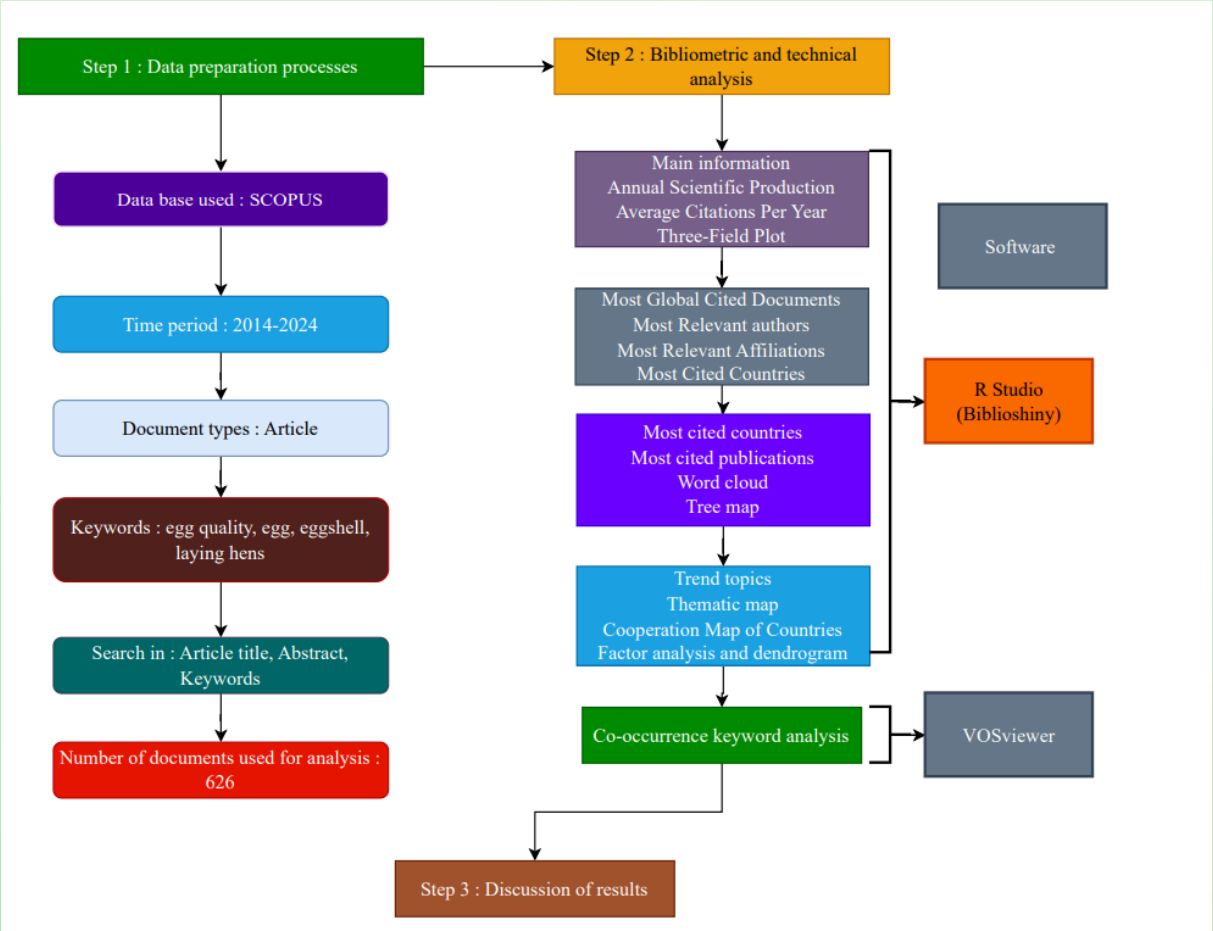


Figure 1. Diagram of the analytical process adopted

Table 2. Method for extracting recent data from Scopus

Keyword	Included	Excluded
Eggquality, egg, shell, laying hens	Document type:Article, Publication language: English, Source type: Journal, Publication year: 2014-2024	Preprints on preprint servers and e-prints, reviews, conference papers, book chapters, notes, comments, editorials, letters

The studies were downloaded in .csv format and were read in the R studio version 4.4.2 program via the bibliometrix package, as well as in the VOSviewer version 1.6.20 program. In this study, the R bibliometric library(Aria & Cuccurullo, 2017) prepared for bibliometric analysis was preferred and the VOSviewer software (van Eck & Waltman, 2017) was used to visualize the results. The second stage involved data analysis via the applications. A total of 17 analyses were generated using the R studio program via the bibliometrix package and the VOSViewer software, created and visualized 2 bibliometric network maps. The third step, as shown in Figure 1, was to discuss the results of the analysis.

Results of bibliometric analysis of data on factors affecting egg quality

Main information

Figure 2 shows the basic information on publications relating to “egg quality”, “eggs”, “shell” and “laying hens”. Biblioshiny's analysis of these keywords yields the following results.

Thanks to the keywords and precise filtering, the Scopus database revealed a total of 626 articles written between 2014 and 2024. Biblioshiny's analysis of this data revealed that 138 scientific journals were used to publish these articles. With an annual growth rate of 2.66% for publications, this figure also shows that the average age of publications is 4.26 years and that the average number of citations per publication is 11.9. In addition, 16 of the 2579 authors published without co-authors, and international collaboration between authors was 21.09%.

Annual status of scientific publications

Figure 3 shows the annual trend in publications relating to “egg quality”, “eggs”, “shell” and “laying hens”.



Figure 2. Main information

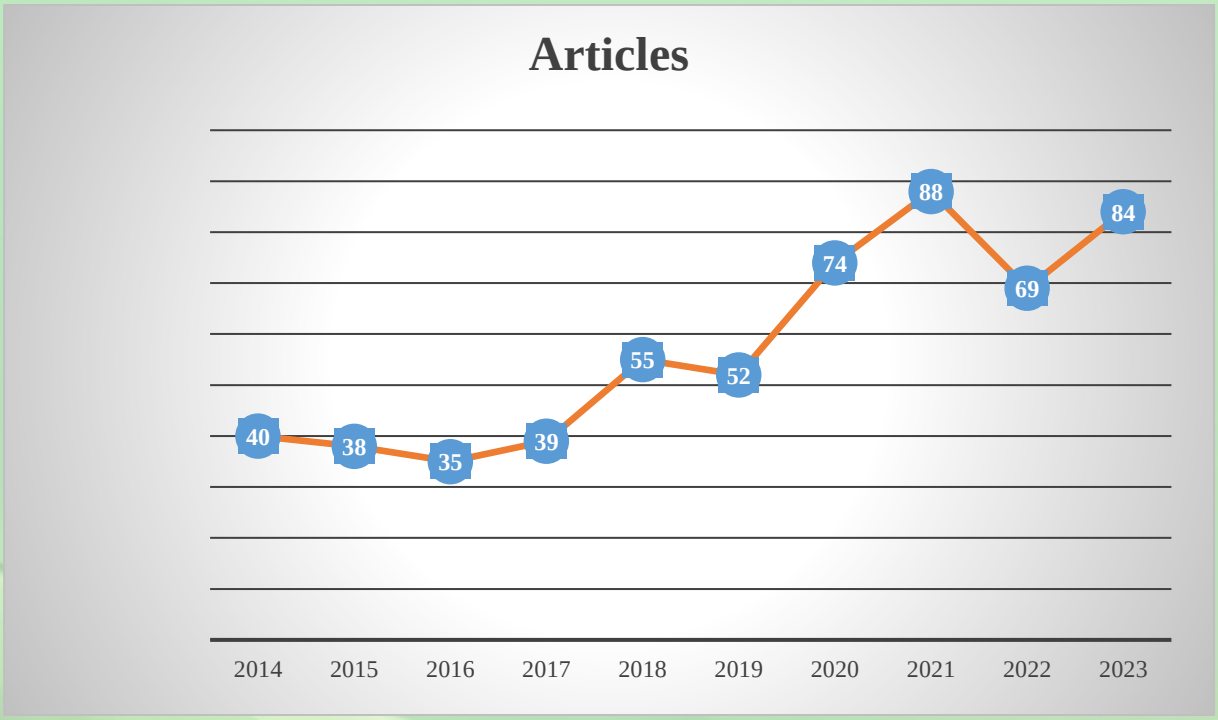


Figure 3: Annual status

Figure 3 shows that the annual publication of scientific articles related to the above keywords varies from year to year. Thus, in 2014, there were 40 articles published, 38 in 2015, 35 in 2016, 39 in 2017, 55 in 2018, 52 in 2019, 74 in 2020, 88 in 2021, 69 in 2022 and 84 articles published in 2023. This figure also reveals that the publication of scientific articles related to “egg quality”, “eggs”, “shell” and “laying hens” has almost doubled in the last three years. However, 2021 is the year in which most articles were produced.

Average annual citations by publication

Figure 4 shows the average total citations per article for “egg quality”, “eggs”, “shell” and “laying hens”. Figure 4 shows the average total citations per article for “egg quality”, “eggs”, “shell” and “laying hens”.

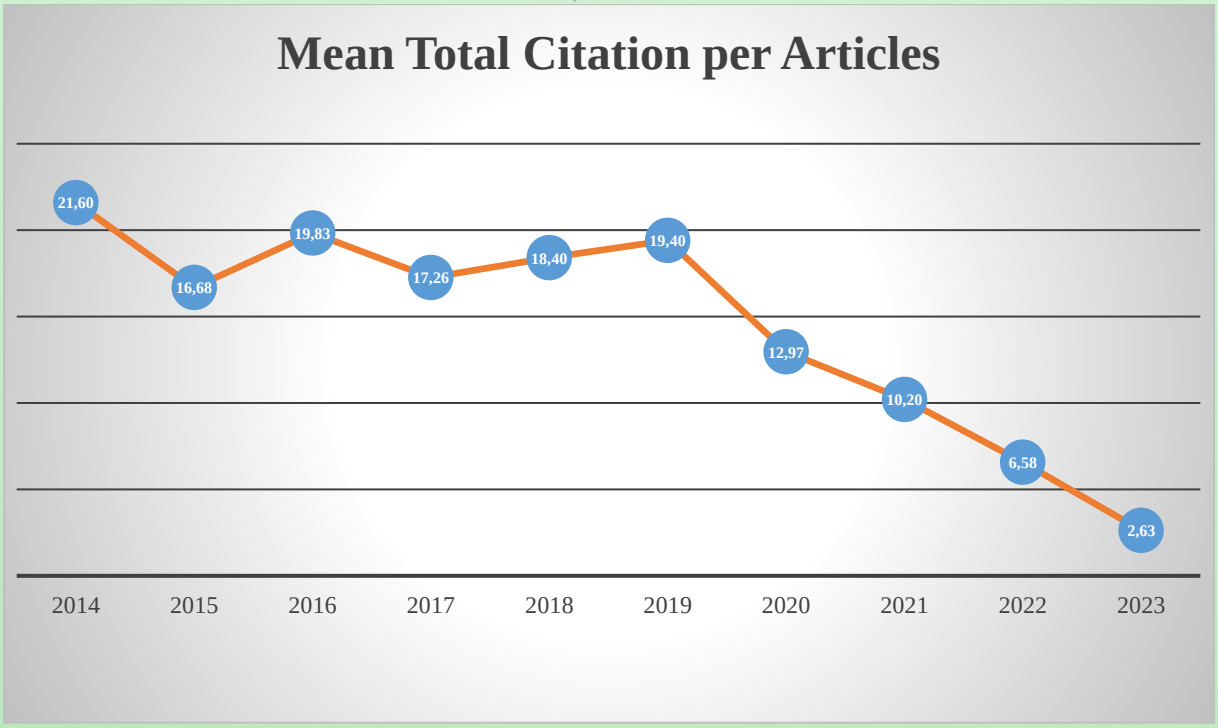


Figure 4. Annual status of citations

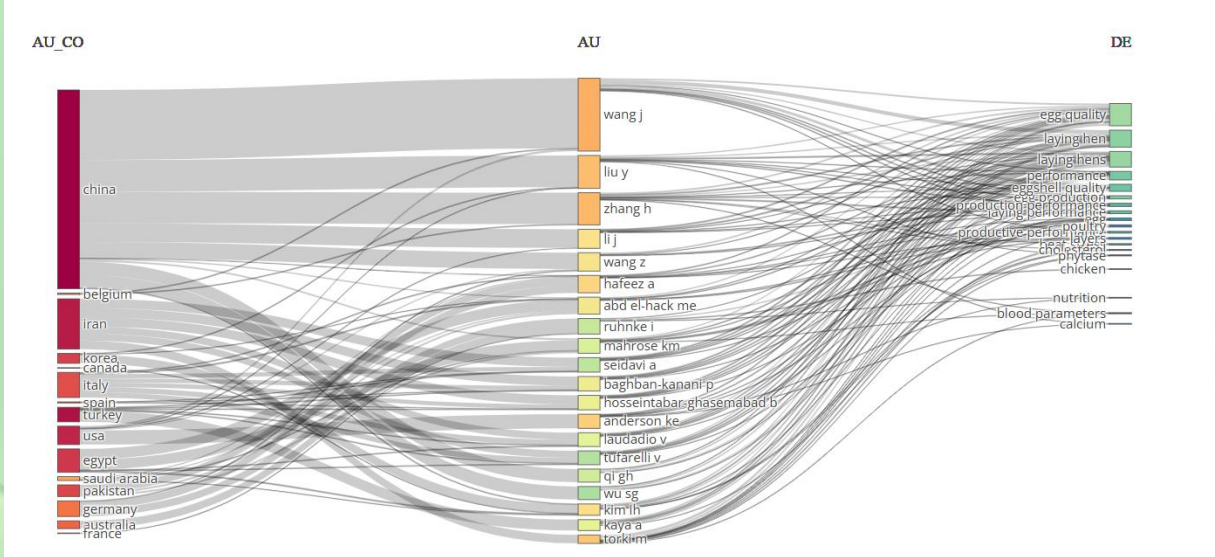


Figure 5. Three field diagrams

This figure shows that in the year 20214, the annual average of total citations per article relating to “egg quality”, “eggs”, “shell” and “laying hens” is 21.6. This number has fallen considerably over time. In 2015 it was 16.68, 19.83 in 2016, 17.26 in 2017, 18.40 in 2018 and 19.4 in 2019. From 2020 to 2023, the annual average of total citations per article is below 15. The year 2023 has the lowest average per article.

Sankey diagram

Thanks to Biblioshiny, the Sankey diagram has been drawn up. This diagram takes three parameters into account. These include “countries”, “authors” and “keywords”. Figure 5 shows this diagram.

This diagram shows that the country that has produced the most scientific articles relating to “egg quality”, “eggs”, “shell” and “laying hens” is none other than “China”. The most published author is “Wang J” and the most recurrent keyword is none other than “egg quality”.

Most productive scientific journals

Table 3 shows the 10 scientific journals with the most articles published in connection with “egg quality”, “eggs”, “shell” and “laying hens”.

From this table, we can see that Poultry Science, Animals and Frontiers in Veterinary Science are the scientific journals with the most articles published, with 123, 70 and 23 articles published respectively. Poultry Science tops the list, followed by the other two scientific journals.

Most productive authors

Figure 6 shows the authors with the most articles published on "egg quality", "eggs", "shell" and "laying hens". This figure reveals that Wang J, Zhang H and Liu Y are the authors who have written the most articles related to "egg quality", "eggs", "shell" and "laying hens". Compared with the other two authors, Wang J alone wrote 26 articles, which puts him in first place in this ranking. Zhang H and Liu Y have written 13 and 12 papers respectively, taking second and third place.

Universities with the most publications

Universities were also involved in writing and publishing articles on "egg quality", "eggs", "shell" and "laying hens", as shown in Table 4. According to this table, the universities with the most research and publications related to the above keywords are none other than Sichuan Agricultural University, China Agricultural University and Feed Research Institute, with 85, 78 and 62 articles respectively. Sichuan Agricultural University tops the list.

Table 3. Most important journals

Sources	Articles
POULTRY SCIENCE	123
ANIMALS	70
FRONTIERS IN VETERINARY SCIENCE	20
BRITISH POULTRY SCIENCE	17
EUROPEAN POULTRY SCIENCE	14
REVISTA BRASILEIRA DE CIENCIA AVICOLA / BRAZILIAN JOURNAL OF POULTRY SCIENCE	13
ANIMAL NUTRITION	12
JOURNAL OF ANIMAL PHYSIOLOGY AND ANIMAL NUTRITION	12
TROPICAL ANIMAL HEALTH AND PRODUCTION	12
ANIMAL NUTRITION AND FEED TECHNOLOGY	11

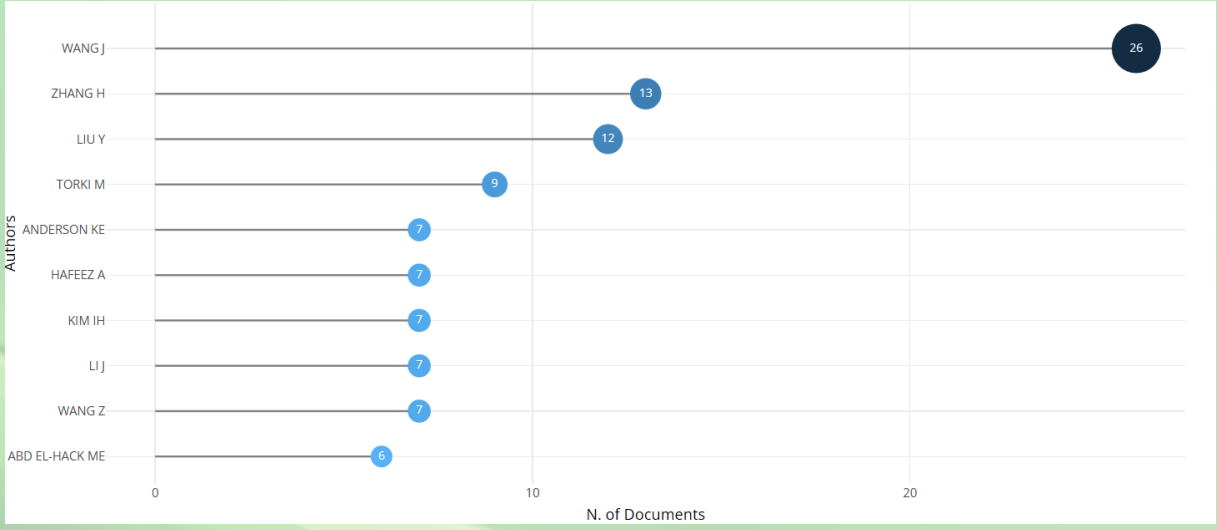


Figure 6. Most prolific authors

Table 4. Most important universities

Affiliation	Articles
SICHUAN AGRICULTURAL UNIVERSITY	85
CHINA AGRICULTURAL UNIVERSITY	78
FEED RESEARCH INSTITUTE	62
NORTHWEST AANDF UNIVERSITY	44
ZHEJIANG UNIVERSITY	43
HEBEI AGRICULTURAL UNIVERSITY	37
UNIVERSITY OF VETERINARY AND ANIMAL SCIENCES	34
UNIVERSITY OF NEW ENGLAND	33
HUAZHONG AGRICULTURAL UNIVERSITY	32
SHANDONG AGRICULTURAL UNIVERSITY	31

Scientific output by country

Figure 7 shows the most active countries in terms of article production in relation to “egg quality”, “eggs”, “shell” and “laying hens”. On the map, the colors dark blue, blue and gray indicate respectively the country with the most dissemination, the country with the least dissemination and the country with no dissemination (Demir, Chatterjee, Kadry, et al., 2024). The table on the map shows the 10 countries that produce the most articles related to “egg quality”, “eggs”, “shell” and “laying hens”. The table shows that China (928) has produced the most scientific articles. It is followed by Brazil (301) and Turkey (210).

Scientific collaboration between countries

Figure 8 shows a map of worldwide collaboration on studies involving keywords such as “egg quality”, “eggs”, “shell” and “laying hens”. The figure shows that Egypt's collaboration with Saudi Arabia, with a total of 14 documents produced, is in first place. In second place, with 12 documents produced, is the collaboration between China and the USA. In third place was the collaboration between China and Egypt, with 6 documents produced. However, China also collaborated with Pakistan, and the USA in turn collaborated with Germany and the UK. These various collaborations between countries demonstrate the extent to which the factors influencing egg quality are a topical issue worldwide.

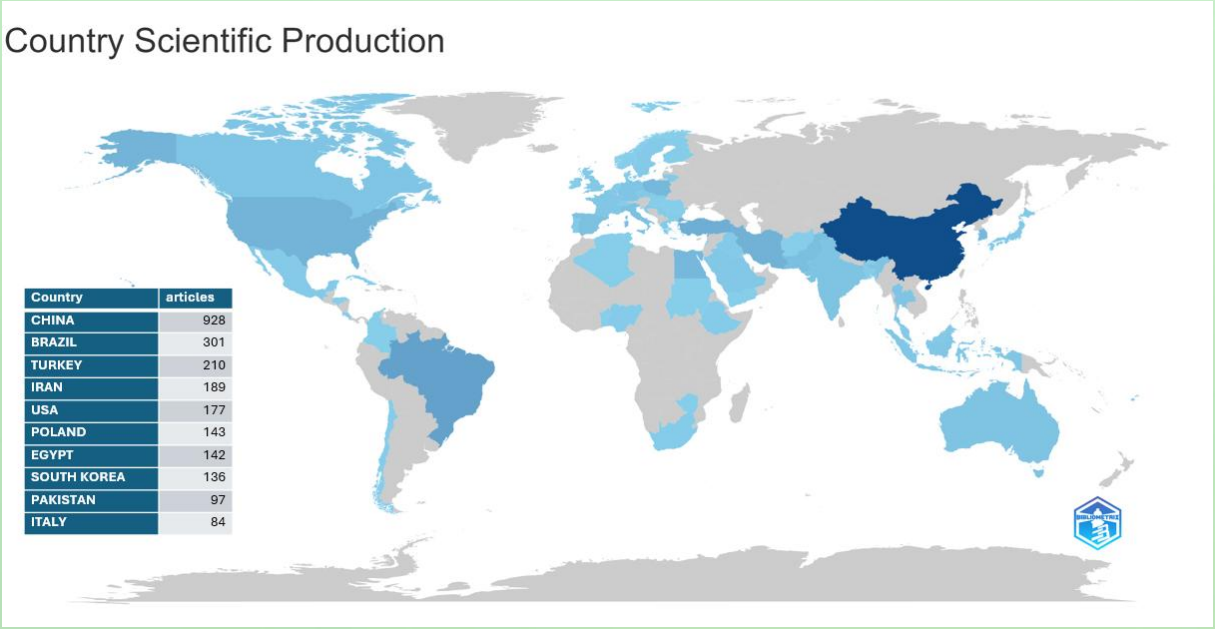


Figure 7. Most productive countries

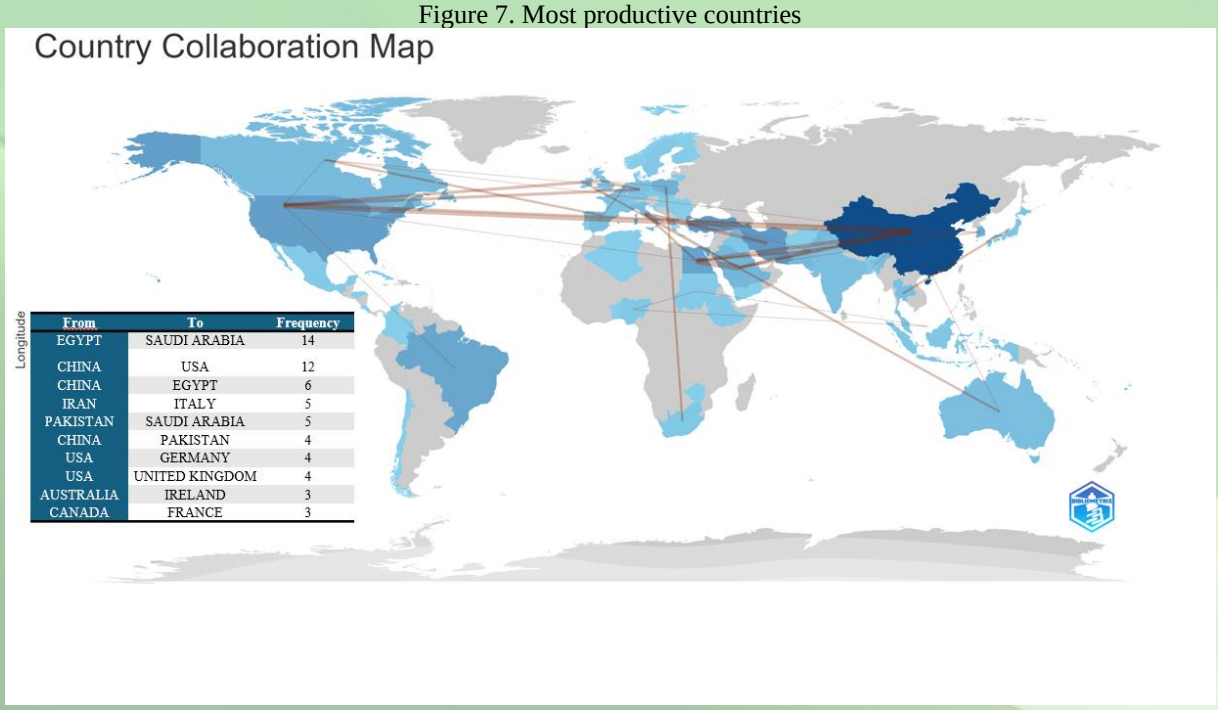


Figure 8. Cooperation map of countries

Most referenced countries

Table 5 shows the most cited countries for topics relating to “egg quality”, “eggs”, “shell” and “laying hens”. The table shows that, of the 10 countries mentioned, China is the most referenced, with 1905 citations. The USA takes second place with 580 citations and Egypt, with 459 citations, takes third place among the most referenced countries.

Most important documents

Table 6 refers to the 10 most cited documents. The most cited document refers to the article or research paper that has accumulated the highest total number of citations from other academic works. In other words, it is the article that has been most referenced by other researchers and has therefore received the greatest cumulative number of citations(Demir, Chatterjee, &Pamucar, 2024).

Table 5. Most cited countries

Country	Total Citation
CHINA	1905
USA	580
EGYPT	459
IRAN	398
TÜRKİYE	377
KOREA	313
BRAZIL	311
AUSTRALIA	284
ITALY	277
POLAND	274

Table 6. Most cited publications

Paper	DOI	Total Citations
STEFANELLO C, 2014, POULT SCI	https://doi.org/10.3382/ps.2013-03190	117
KAWASAKI K, 2019, ANIMALS	https://doi.org/10.3390/ani9030098	110
BARRETT NW, 2019, POULT SCI	https://doi.org/10.3382/ps/pez541	91
AL-QAZZAZ MFA, 2016, REV BRAS ZOOTEC	https://doi.org/10.1590/S1806-92902016000900003	82
GUO Y, 2020, POULT SCI	https://doi.org/10.1016/j.psj.2019.12.032	80
DUMAN M, 2016, EUROPEAN POULT SCI	https://doi.org/10.1399/eps.2016.117	80
MIGNON-GRASTEAU S, 2014, POULT SCI	https://doi.org/10.3382/ps/pev028	77
XIAO JF, 2014, POULT SCI	https://doi.org/10.3382/ps.2013-03354	76
SAMIULLAH S, 2017, POULT SCI	https://doi.org/10.3382/ps/pew289	74
PARK JW, 2016, POULT SCI	https://doi.org/10.3382/ps/pew241	73

According to this table, of the 10 most cited articles, the most cited article is entitled “Productive performance, eggshell quality, and eggshell ultrastructure of laying hens fed diets supplemented with organic trace minerals” (Stefanello et al., 2014). Published in the journal Poultry Science, it alone totals 117 citations. The second most cited article is “Evaluation of Black Soldier Fly (Hermetia illucens) Larvae and Pre-Pupae Raised on Household Organic Waste, as Potential Ingredients for Poultry Feed” (Kawasaki et al., 2019). With 110 citations, it is published in the journal Animals. The most cited article occupying third place with 91 citations is “Effects of acute and chronic heat stress on the performance, egg quality, body temperature, and blood gas parameters of laying hens” (Barrett et al., 2019). It is published in the journal Poultry Science.

Word cloud

Figure 9 shows the word cloud related to “egg quality”, “eggs”, “shell” and “laying hens”.
Generated using the Biblioshiny program, Figure 9 shows that the keywords “egg quality”, “laying hens” and “laying hen” are those most often used in articles relating to “egg quality”, “eggs”, “shell” and “laying hens”.

Tree map

Figure 10 shows the frequency of keyword use.



Figure 9. Word cloud

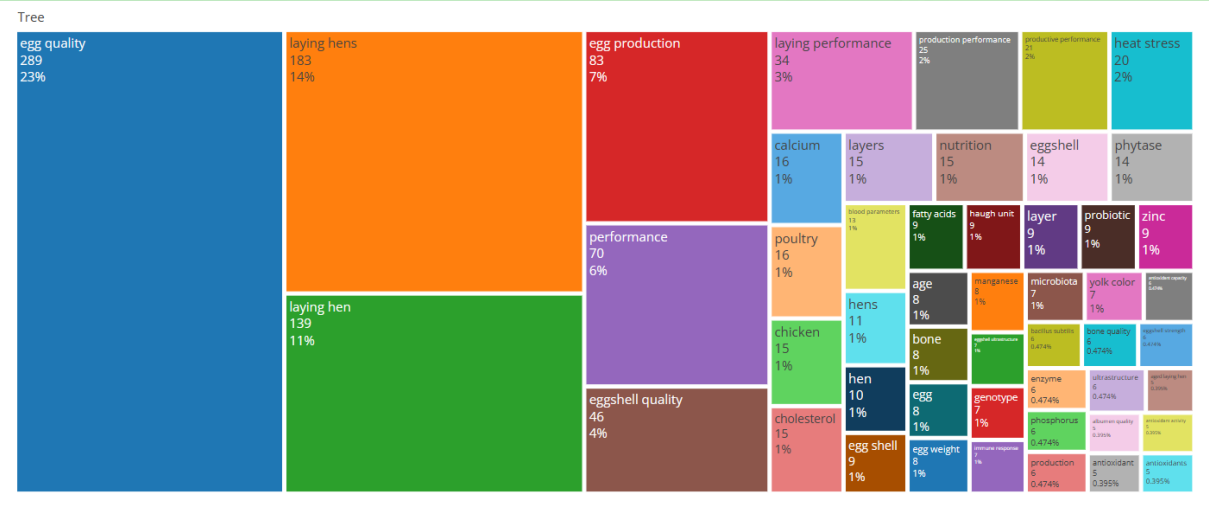


Figure 10. Tree map

According to this figure, “egg quality”, “laying hens” and “laying hen” have the highest usage rates. “Egg quality”, as shown in the blue rectangle, is the most frequently used keyword, accounting for 23% of all keywords. In second place comes “laying hens”. It occupies the orange rectangle and has a 14% usage rate. Finally, in third place comes the keyword “laying hen”, with an 11% usage rate. It can be seen in the green rectangle.

Trend topics

Trend topics in the literature related to the keywords “egg quality”, “eggs”, “shell” and “laying hens” from 2014 to 2024 are shown in Table 7.

From the elements of this table, the dominant trending theme during the first quarter of 2017, the second quarter of 2020 and the third quarter of 2022 was “egg quality”. Similarly, during the first quarter of 2018, the second quarter of 2020 and the third quarter of 2022, the trending term was “laying hens”. Finally, “laying hen” was the trending theme in Q1 2018, Q2 2021 and Q3 2022.

Author's keyword theme map

To make a visual representation of the existing relationships between words, topics or keywords used in the research literature, a thematic map was made. Figure 11 shows that studies carried out in connection with keywords such as “egg quality”, “eggs”, “shell” and “laying hens” are grouped under 4 distinct themes with different intensities.

Table 7.Trending topics

Term	Frequency	Year (Q1)	Year (Q2)	Year (Q3)
Egg quality	289	2017	2020	2022
Laying hens	183	2018	2020	2022
Laying hen	139	2018	2021	2022
Egg production	83	2017	2020	2022
Performance	70	2016	2018	2021
Eggshell quality	46	2018	2021	2023
Production performance	25	2020	2021	2022
Heat stress	20	2015	2018	2022
Poultry	16	2020	2022	2023
Nutrition	15	2015	2018	2022

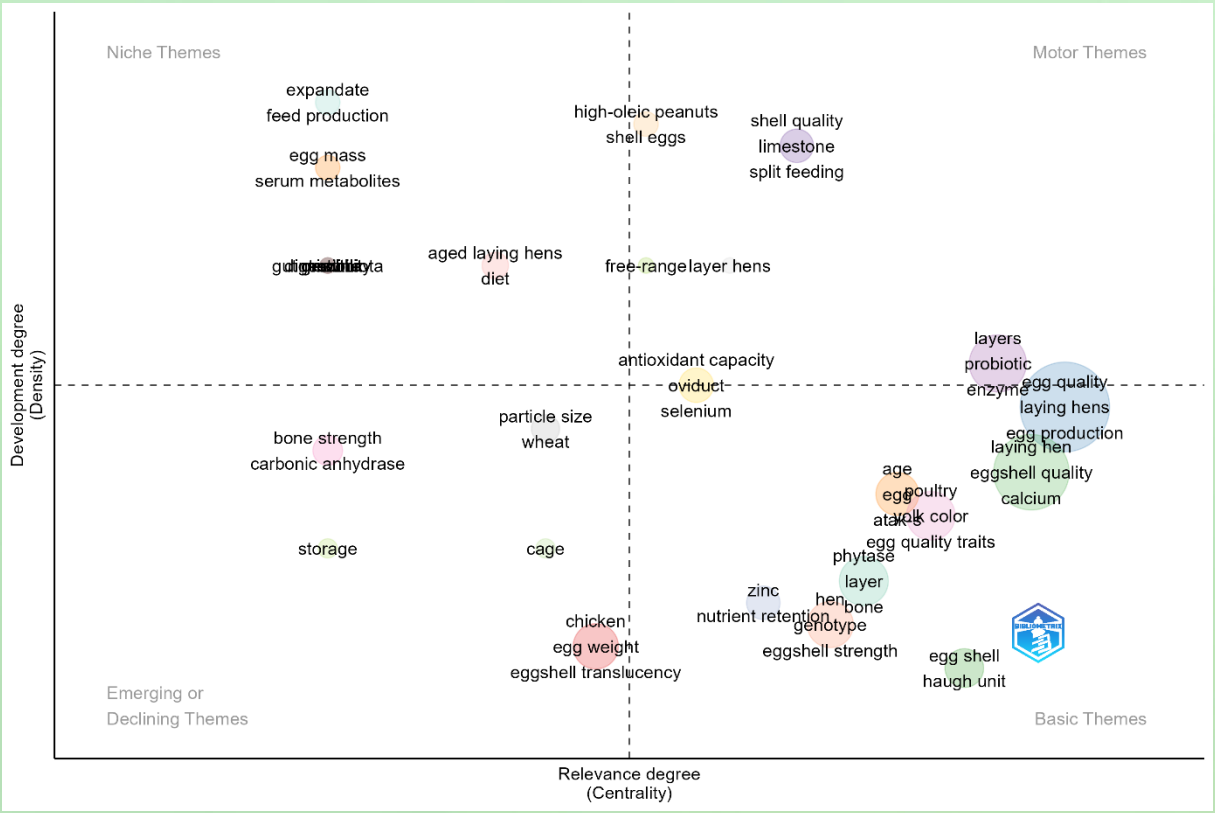


Figure 11. Thematic map

When the author's keywords were considered, the niche themes were “expandate, feed production, egg mass, serum metabolites”. The driving themes were “shell quality, limestone, layers, probiotic”. For basic themes, the keywords were “haugh unit, phytase, zinc, age, eggshell strength”. For emerging or declining themes, the keywords were “storage, cage, bone strenght, carbonic anhydrase, egg weight...”.

Author keyword co-occurrence analyses

To facilitate the identification of an article, keywords are generally used. The prevalence of a keyword in an article underlines its importance. To highlight the joint effects of working with a set of keywords and the research knowledge base, VOSviewer was used. By examining the keywords indexed in the articles, a total of 1,450 keywords were identified. 148 keywords were considered in the analysis below, and the threshold value in VOSviewer was set at 3. The results of this analysis are shown in figure 12.

From this figure, we can see that different colors are used to represent different keywords. However, each circle in the visualization shows the inclusion of a particular keyword in the sub-domains of the network theme of factors affecting egg quality. Of these different circles, the most imposing determined from the quantity of elements they encompass are respectively “egg quality” (group 1), “laying hens” (group 2) and “eggs production” (group 3). The similarly colored circles represent the distribution in a comparison region. Group 1 (egg quality) is shown in blue. Keywords in this group include eggshell quality, laying performance, production performance... In group 2 (laying hens) represented by brown, keywords include cholesterol, heat stress, production performance... As for group 3 (eggs production) represented by green, keywords in this group include probiotic, nutrition, zinc, vitamin E...

As shown in figure 13, the VOSviewer software also enabled the use of the "visualization by overlay" technique. This technique was used to facilitate the incorporation of keywords with distinct colors corresponding to the year of publication.

In this case, the average publication year (yellow) for the newly introduced terms is 2022. Based on the time elapsed since their publication, the colors of the elements have been determined. Figure 12 illustrates the period from 2018 to 2022, represented by the progression of purple-green-yellow colors. On the one hand, keywords such as bacillus subtilis, eggshell, probiotics and nutrient digestibility were studied during the period 2018-2022. On the other hand, it has been observed that in recent times, keywords such as antioxidants, oxidative stress, calcium and health status have been included in scientific publications.

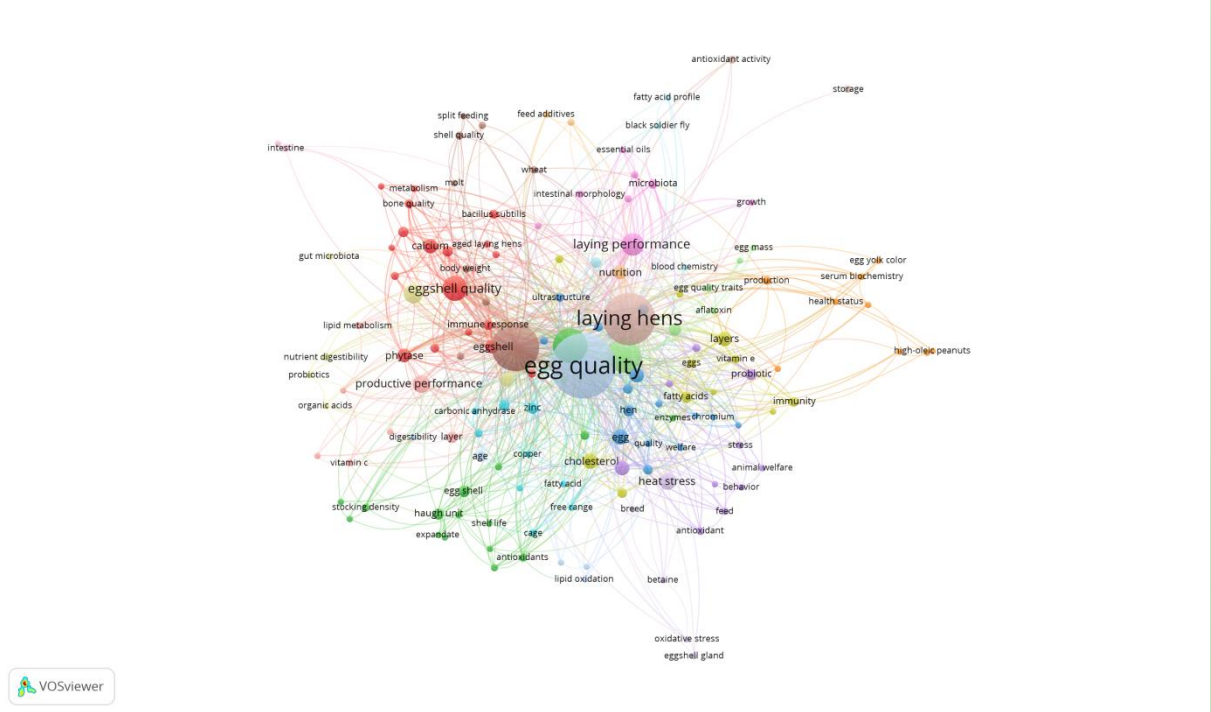


Figure 12. Keyword network map

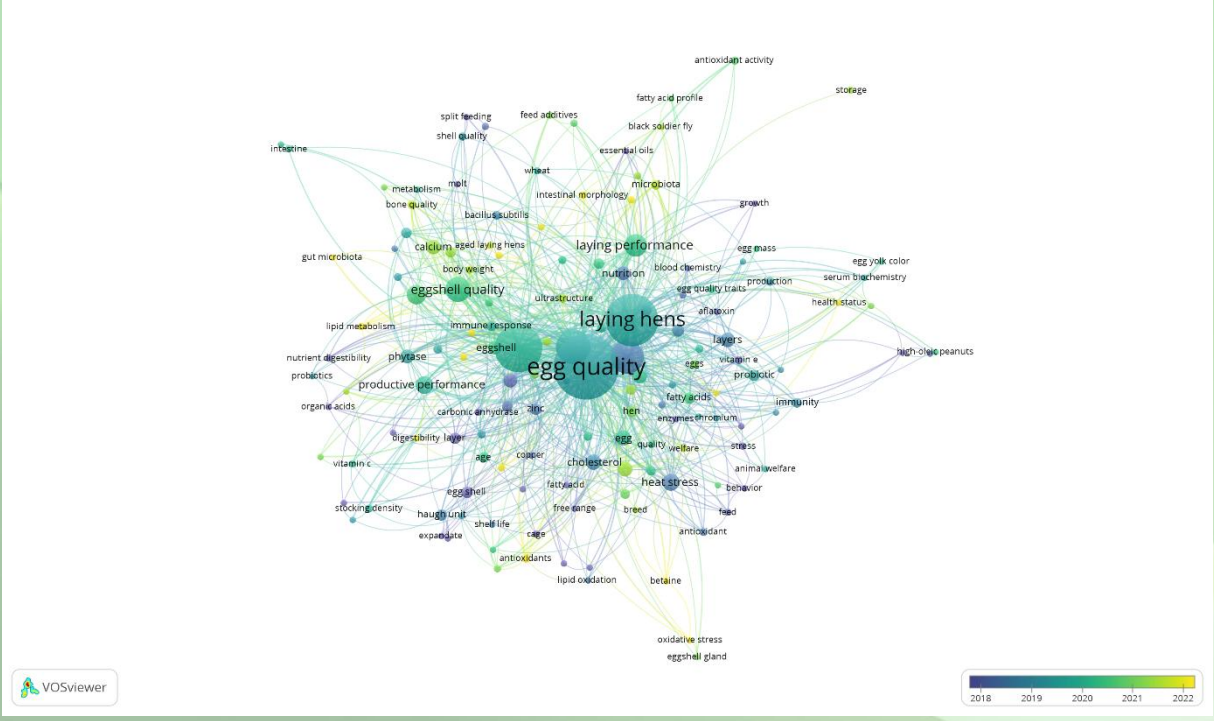


Figure 13. Timeline of keywords

Factor analysis of author keywords

To reduce complexity and shed light on hidden structures in multivariate data sets factor analysis is generally used. In other words, this statistical technique facilitates the understanding and management of relationships between variables in a data set. Keyword factor analysis is shown in figure 14.

When analyzing keywords relating to factors influencing egg quality, keywords such as “yolk color, fatty acids, production, xylanase, shell quality, zinc and eggshell” are grouped together in the blue cluster due to their high factor loadings. On the other hand, within the same cluster, keywords such as “probiotic, egg quality, stocking density, nutrition, genotype, aged laying hen, eggshell ultrastructure, vitamin D3, blood parameters antioxidant...” are represented by small triangles. In parallel, keywords such as “body weight, albumen quality, manganese, ultra structure, tibia, bone strength and eggshell quality” make up the red cluster, and keywords such as “phytase, bone, eggshell, bone quality, phosphorus, calcium and bacillus subtilis” in turn form the green cluster.

Dendrogram

Dendrograms are tree-shaped graphs showing the structural relationships obtained because of hierarchical cluster analysis(Demir, Chatterjee, Kadry, et al., 2024). Used in bibliometric analyses, they enable the identification of topics with which articles share a certain similarity or are directly related. Figure 15 shows a thematic dendrogram to illustrate the hierarchical relationship between keywords.

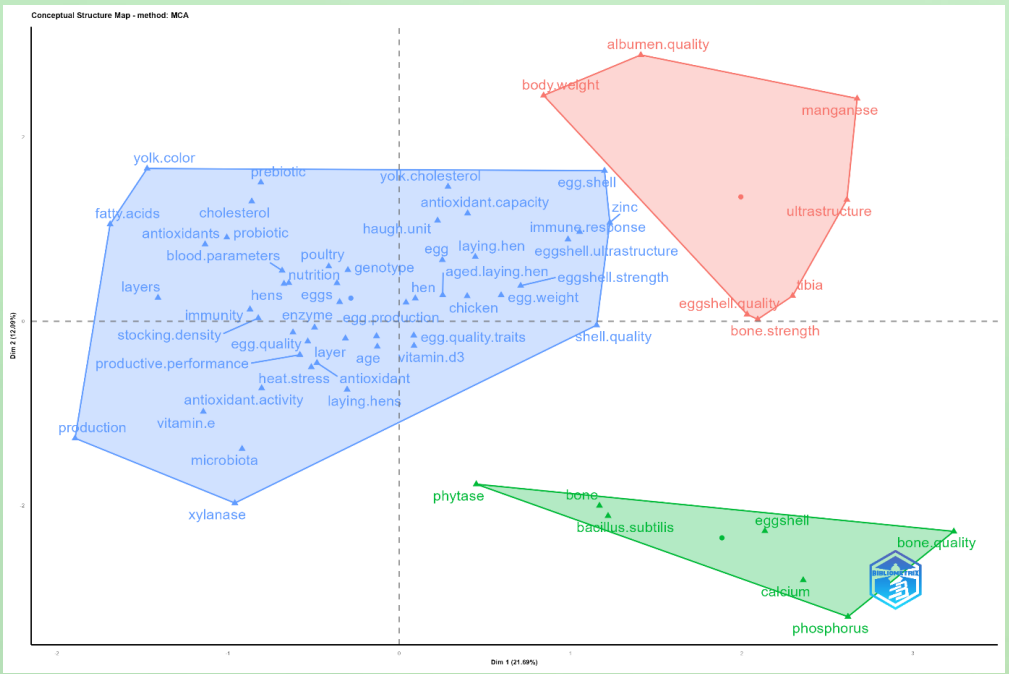


Figure 14. Factor analysis of author-keywords

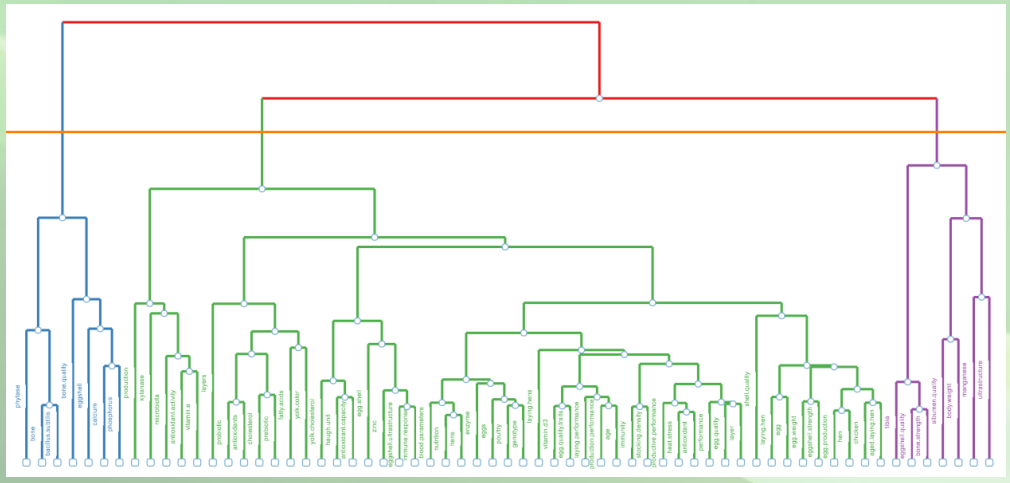


Figure 15. Topic dendrogram of author keywords

Discussion

Below the orange horizontal line of the thematic dendrogram in figure 15, the keywords are divided into three distinct groups (blue, green and violet). These clusters highlight how the themes relate to each other. In the blue cluster, the terms or topics that are linked are "phytase, bone, bacillus subtilis, eggshell, calcium and phosphorus". Furthermore, in the green cluster, relevant terms that share a certain similarity include: "production, xylanase, vitamin, antioxidants, genotype, egg quality, aged laying hen...". For the purple cluster, the associated topics are "tibia, eggshell quality, bone strength, albumen quality, body weight, manganese and ultrastructure".

The quality of eggs produced by laying hens has been the subject of much debate in recent years. With the aim of identifying and controlling the factors that can affect egg quality, research in recent years has been devoted to this topic. The number of publications and citations in this field are indicators of the interest and progress made by researchers(Roberts, 2004; Stefanello et al., 2014; Kawasaki et al., 2019; Hisasaga et al., 2020; Abebe et al., 2023; Batkowska et al., 2023). Over the past three years, there has been a significant increase in annual publications on factors that can affect egg quality, and so far, the highest number of articles has been reached in 2021. The annual number of publications increased slowly from 2014 to 2017, with fewer than 50 articles per year. The increase observed from 2018 onwards could probably be explained following an awareness of the impact of factors on laying hen productivity as well as egg quality. Indeed, there are certain factors that influence both the productivity of laying hens and the quality of their eggs (Travel et al., 2010; Seven et al., 2011; Barrett et al., 2019; Ward, n.d.). The most cited international literature testifies that trace element supplementation(Stefanello et al., 2014; Xiao et al., 2014), protein source replacement (Al-Qazzaz et al., 2016; Kawasaki et al., 2019), heat stress (Barrett et al., 2019; Mignon-Grasteau et al., 2015), the use of prebiotics(Guo et al., 2020), probiotics(Park et al., 2016), the type of production system and the age of layinghens(Samiullah et al., 2017) are factors that could well affect egg quality and laying hen productivity. In short, the major factors affecting egg quality include feed, type of production system, age and temperature. The following studies corroborate this assertion (Petersen, 1965; Travel et al., 2011; John-Jaja et al., 2017). Similarly, the last 5 years have seen a 63.9% increase in annual scientific output, coupled with a significant drop in the average number of citations per publication, highlighting a negative correlation between publication volume and impact.

Furthermore, China stood out for its major quantitative contribution to research into factors affecting the quality of laying hen eggs, ranking first in terms of publications, lead authors and institutional affiliations. In addition, the study of international collaborations revealed close links between China and countries such as the USA, Pakistan and Egypt, particularly in the field of factors affecting hen egg quality. The study also revealed that of the top 10 research universities, the top 2 were Chinese. "Sichuan Agricultural University was the most productive in terms of egg quality research overall. As for the authors, Wang J, Liu Y and Zhang H, they contributed relatively to egg quality research. Wang J focused much more on factors such as feed, production system, gut microbiota during his egg quality research(X. L. Wang et al., 2009; J. Wang et al., 2017; X. C. Wang et al., 2017; X. Wang et al., 2017, 2018; Dai et al., 2022). As far as Liu Y and Zhang H are concerned, they have mainly focused their research on nutrition, on diet supplementation and the use of probiotics in laying hen feed.

They tested a multitude of diets for laying hens to assess their impact on egg quality(F. Chen et al., 2021; H. N. Liu et al., 2014; Y. Liu et al., 2017, 2021, 2023; Y. J. Liu et al., 2019; Xiang et al., 2019; Y. N. Zhang, Wang, et al., 2017; Y. N. Zhang, Zhang, Wang, et al., 2017; Y. N. Zhang, Zhang, Wu, et al., 2017).Bibliometric analysis of document sources (including journals, books, etc.) is important to provide up-to-date information and trends for a particular research area, as well as to guide researchers in selecting appropriate journals for their research communication (Cheng et al., 2022; F.-H. Liu et al., 2022). Poultry Science, Animals and Frontiers in Veterinary Science have established themselves as the main platforms for disseminating research on factors influencing egg quality in laying hens.

To facilitate indexing and searching of an article, authors generally propose a list of keywords that reflect the main ideas developed in their work. In this study, the terms "egg quality", "laying hens", "egg production" and "performance" recur repeatedly in the dataset analyzed through the word cloud (WordCloud), heat map (TreeMap) and trend analysis (Trend Topics), confirming the centrality of these keywords to the field in relation to factors affecting egg quality. Analysis of the keyword thematic map makes it possible to organize keyword groupings according to density and centrality in a single circle for mapping as a two-dimensional image (Ejaz et al., 2022).

From the Author's Keywords, it was identified that driving topics including "shell quality", "limestone", "layers" and "probiotic" have been well studied in relation to factors affecting egg quality in laying hens (Mohan et al., 1995; J. L. Zhang et al., 2012; Gholiabad et al., 2014; Ray et al., 2022). However, some topics that have been weakly developed among both emerging and declining themes (storage, cage, bone strenght, carbonic anhydrase, egg weight) and core themes (haugh unit, phytase, zinc, age, eggshell strength) could be of research interest for further studies on factors affecting egg quality in laying hens. The co-occurrence network of all the keywords revealed that current research on factors affecting egg quality focused mainly on laying hens as research topics (red nodes), on performance studies of these hens (green nodes) and on eggshell quality and strength (blue nodes). To our knowledge, the present study is the first to examine the state of global research and emerging trends on factors affecting egg quality using the bibliometric approach between 2014 and 2024. This analysis focuses on

publications indexed in the Scopus database. Considered as a literature review during this period, the present study aims to understand scientific productivity, keywords, publication trends and important factors affecting egg quality in laying hens. The results of this study pave the way for new perspectives and research directions about egg quality.

Conclusion

This study inspected and evaluated the scientific achievements made in the field of research into factors affecting egg quality in laying hens worldwide, using the Scopus database. Key current researchers were identified, and regional distributions and publications were mapped. In terms of countries having produced the most papers in research into factors affecting egg quality in laying hens, China literally stood out from the rest. Wang J was also identified as the most productive author following the results of the bibliometric analysis carried out on factors affecting the quality of eggs from laying hens. The most cited journal for publications related to this study topic is "Poultry Science". "Egg quality", 'laying hens' and 'performance' are the keywords most frequently used by authors. By summarizing the factors affecting egg quality in laying hens, i.e. feed, type of production system, age and temperature, we hope that these results will provide a focus for future research into egg quality. It's true that the Scopus database was the focal point of this study.

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Bibliometric Analysis of the Effects of Feed Additives Used in Broiler Farming on Meat Quality

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Abstract

In recent years, the increasing demand for chicken meat has led to a rise in broiler production. This increase has encouraged the use of various feed additives to further improve the productivity of broilers and enhance their efficiency. This study aims to analyze the extent to which feed additives used in broiler farming over the past 20 years have impacted meat quality. Data on feed additives used in broiler farming and their effects on meat quality were analyzed using bibliometric methods. For this purpose, Scopus and Vosviewer databases were utilized, and articles were screened using the keywords "broiler," "feed," "supplements," and "meat quality." A total of 536 documents were reviewed. The data from these documents were analyzed using the "Biblioshiny" and "Excel" software packages. Analysis of articles using these keywords by publication year showed that 2012 had the highest number of publications, with 13 articles. Citation analysis revealed that the year with the most citations was 2007, with an increase of 104.67%. Among the countries conducting the most research, China was identified as the leading contributor. The most prolific author was Kim IH. During the period between 2004 and 2014, *Poultry Science* emerged as the most significant journal with 156 published articles, followed by *British Poultry Science* with 46 articles, and *Tropical Animal Health and Production* with 18 articles. Among the keywords "broiler," "feed," "supplements," and "meat quality," the most frequently researched term was "meat quality." The university with the highest number of publications was *Nanjing Agricultural University*, while China stood out as the country with the most citations and the highest level of collaboration. Among collaborative efforts, China and Saudi Arabia were prominent partners. Frequently used terms in the analyzed studies included "diet," "chickens," "animal feed," "dietary supplement," and "meat." This study investigated the changes and developments in the effects of feed additives on meat quality over the years, aiming to identify the substances affecting quality, their varieties, and their usage levels over time. It is anticipated that this study will guide and contribute to future research on feed additives, their application goals, and potential innovations in poultry farming.

Key Words: *broiler, feed, supplements, meat quality, bibliometric analysis, Biblioshiny, VOSviewer*

Broyler Yetiştiriciliğinde Kullanılan Yem Katkı Maddelerinin Et Kalitesi Üzerine Etkilerinin Bibliyometrik Analizi

Özet

Son yıllarda artan tavuk eti tüketim talebine bağlı olarak etçi tavuk üretiminde de artış görülmektedir. Bu artış etçi tavukların verimini daha da geliştirmek, alınan yararlanımı arttırmak için çeşitli yem katkı maddelerinin kullanımını teşvik etmiştir. Bu çalışmada son 20 yılda broyler yetiştiriciliğinde kullanılan yem katkı maddelerinin et kalitesi üzerinde ne derece değişiklikler meydana getirdiğini analiz etmek hedeflenmiştir. Broyler yetiştiriciliğinde kullanılan yem katkı maddeleri ve et kalitesine etkisi hakkında veriler bibliyometrik analiz ile çalışılmıştır. Bu amaç doğrultusunda Scopus ve Vosviewer veri tabanı kullanılmış, 'broiler', 'feed', 'supplements', 'meat quality' anahtar kelimeleri ile makaleler taranmıştır. Bu tarama için 536 doküman incelenmiştir. Bu dokümanın içerdiği verilerin analizi için 'Biblioshiny' ve 'excel' paket programları kullanılmıştır. 'Broiler', 'feed', 'supplements', 'meat quality' anahtar kelimelerinin kullanıldığı makaleler yıllara göre incelendiğinde en çok yayın yapılan 13 makale ile 2012 yılı olmuştur. Bu anahtar kelimeler ile yapılan atıflar incelendiğinde %104,67 ile 2007 yılı en çok atıf yapılan yıl olmuştur. Yapılan çalışmalar incelendiğinde en çok çalışma yapan ülke Çin olarak tespit edilmiştir. En üretken yazar olarak ise Kim İH. Karşımıza çıkmaktadır. 2004-2014 yılları arasında yapılan çalışmalarda yayımlanan 156 makale ile' Poultry Science' en önemli dergi olmuş, 46 makale ile 'British Poultry Science 'ile ikinci sırada yer almış, 'Tropical Animal Health and Production 'dergisi ise 18 makale ile üçüncü sırada yer almıştır. 'Broiler', 'feed', 'supplements', 'meat quality' anahtar kelimeleri arasında en çok araştırılan kelime 'meat quality' olmuştur. En çok yayın yapan üniversite 'Nanjıng Agricultural University' olurken en çok atıf alan ve en çok iş birliğinde bulunan ülke Çin olmuştur. En sık iş birliği yapan ülkeler incelendiğinde Çin ve Suudi Arabistan öne çıkmaktadır. Yapılan araştırmalarda ön plana çıkan ve sıklıkla kullanılan kelimeler' diet, 'chickens','animal feed', 'dietary supplement' ve 'meat' olarak tespit edilmiştir. Broyler yetiştiriciliğinde kullanılan yem katkı maddelerinin et kalitesi üzerine etkilerinin yıllar içindeki değişimi ve gelişimini araştırmak için yapılan bu çalışma da kaliteyi etkileyen maddelerin tespiti, çeşitleri ve yıllara göre kullanılma düzeylerini tespit etmek amaçlanmıştır. Bu çalışmanın ilerleyen dönemlerde yapılacak olan yem katkı maddeleri araştırmaları ve kullanım hedeflerine, tavuk yetiştiriciliğinde gidilebilecek olan yeniliklere yol gösterici olabileceği ve katkı sağlayabileceği düşünülmektedir.

Anahtar Kelimeler: *broiler, feed, supplements, meat quality, bibliometrik analiz, biblioshiny, Vosviewer*

Giriş

Günümüzde tavuk etine artan talebe bağlı olarak tavuk eti üretiminde de artış gözlenmektedir. Bu artan talep oranı çeşitli sebeplerle ilişkilendirilebilir. Tavuk göğüs eti, tüketici talebine uygun olarak düşük yağ, sodyum ve kolesterol içeriği ile karşımıza çıkmaktadır (Cavani ve ark., 2009). Etçi tavuk olarakta bilinen broyler, tavuk eti tüketimini karşılamak için tercih edilen tür konumuna gelmiştir. Artarak ilerleyen broyler üretimi günümüzde yaygınlaşmışken, şu anda broyler etinin çeşitli özelliklerini değiştirerek et kalitesini artırmaya yönelik çalışmalar yapılmaktadır. Görünüm, doku, sulu olma, su içeriği, sertlik, yumuşaklık, koku ve tat, tüketicilerin et ürününü satın almadan önce ve sonra yaptığı ilk ve son kalite değerlendirmesini etkileyen en önemli ve algılanabilir et özellikleridir (Mir ve ark.,2017). Bu artan tavuk eti talebini karşılamak için, broyler eti üretiminde önemli gelişmeler kaydedilmiştir. Örneğin, 1957 yılında 42 günlük broylerlerin ağırlığı yaklaşık 586 g ve yemden yararlanma oranı 2,8 iken günümüz broylerleri 42 günlükken yaklaşık 3278 g ağırlığa sahip olup, yemden yararlanma oranı ise 1,55'tir (Choi ve ark.,2023). Hayvanların bağırsak fonksiyonunun ve et kalitesinin yem katkı maddeleri aracılığıyla olumlu yönde değiştirilmeye çalışma uygulamaları, büyüme performansını ve yem verimliliğini artırmak için önemli bir araç olarak kabul edilmiştir (G K Collington ve ark.,1990). Üretim de performans parametrelerine ek olarak tavuk eti kalitesine katkı sağlamaya yönelik çalışmalar hedeflenmiştir. ''Kalite, bir ürünün bireysel birimlerini ayırt eden ve bu birimin kullanıcıya kabul edilebilirlik derecesini belirlemede anlam taşıyan özelliklerin birleşimidir'' (Groom 1990). Et kalitesinde etkili değişimler meydana getirebilecek faktörler bulunmaktadır. Et kalitesiyle en ilişkili olan faktörler, kesim öncesi ve sonrası uygulamalar, tavuğun yaşı, ırkı ve beslenmesi olarak sıralanmaktadır. (Pelicano ERL ve ark.,2003). Rasyona antibiyotik katılması tavuk gelişimi ile yemden yararlanma verimliliğini olumlu yönde etkilemekte ve olası patojenlerin gelişimini önleme konusunda destekleyici olduğu bildirilmektedir (Stutz ve Lawton, 1984; Gaskins ve diğ., 2002). Avrupa Birliği'nin yemlerdeki antibiyotiklerin profilaktik kullanımını yasaklaması, tavukçuluk endüstrisinde alternatiflerin aranmasını hızlandırmıştır (Janardhana ve diğ., 2009). Bununla birlikte, doğal olarak kullanılan yöntemlerden enzimler, prebiyotikler, probiyotikler ve fitobiyotikler üzerine çalışmalar yapılmasının önü açılmıştır (Dahiya ve ark., 2006; Wei ve Shibamoto 2007; Ndelekwute ve ark., 2015). Fitobiyotikler" ya da "fitojenik yem katkıları" hayvan yemlerine katıldığında fonksiyonel özelliklerinin yanında aromatik özellikleri de bulunan, aromatik ve baharatlı bitkilerden elde edilen bitki özleri için kullanılan bir terimdir (Yeşilbağ, 2007). Çeşitli bitkisel özlerin birtakım işlemlerden geçerek işlenmesi ile öz yağlar elde edilebilmektedir. Bu özler, bitkilerden buhar damıtma yoluyla veya sıkılarak özünü çıkarma yöntemiyle elde edilmektedir. Elde edilen bitkisel özlere; aromatik yağ, uçucu yağ, esansiyel yağ, eterik yağ ya da bitkisel öz yağlar denir. (Yeşilbağ, 2007). Çeşitli yazarlar, hayvan üretiminde antibiyotiklere alternatif olarak kabul edilen çeşitli bileşenleri kapsamlı bir şekilde incelemiş ve karşılaştırmıştır (Langhout, 2000; Mellor, 2000'a, b; Wenk, 2000; Taylor, 2001). Antibiyotik maddelerin kullanılmadığı durumlarda, prebiyotik etki gösteren maddelerim kullanımı, bağırsak florası ve hayvanın yemden yaralanma veriminin arttırılması için olumlu açıdan destek sağlayacak yöntemlerden biri olmuştur. En yaygın olarak araştırılan iki prebiyotik oligosakarit frukto-oligosakaritler (FOS) ve mannan-oligosakaritlerdir (MOS) (G.-B. Kim ve ark.,2010). Yem katkı maddesi olarak kullanılan bir diğer alternatifte bitkisel özlerdir. Bitkisel özlerin kullanımı daha çok kalabalık yetiştirmelerin görüldüğü işletmelerde yem katkı maddesi olarak hayvanın gelişim durumunun olumlu yönde artması amacı ile kullanılmaktadır (J. Abo Omar ve ark., 2016). Bu amaçla çeşitli aromatik bitkilerin rasyona katılması yoluyla besleme yöntemi gerçekleştirilmektedir. Tercih edilen bazı aromatik bitkiler arasında kekik, nane, adaçayı, lavanta gibi çeşitler görülmektedir. Hayvan sağlığı üzerindeki olumlu etkileri; iştah ve yem alımının uyarılması, sindirim enzim salgılanmasının arttırılması, bağışıklık sisteminin iyileştirilmesi ve antiviral, antioksidan ve antihelmintik şeklinde sıralanabilmektedir (Kamal Jamal Issa ve J. M. Abo Omar,2016). Diğer bir popüler yem katkı maddesi ise uçucu yağlardır. Uçucu yağlar, hayvan üretiminde kullanılmak üzere piyasaya sürülmüş ve "sindirim artırıcılar" olarak tanıtılmaktadır (Williams ve Losa, 2001). Uçucu yağ, bitki materyallerinden izole edilebilen, aromatik özelliklere sahip, uçucu bileşiklerin bir karışımıdır (Oyen ve Dung, 1999). Şu ana kadar tavukçuluk üretiminde kullanılan aromatik yağlar arasında kekik (Origanum vulgare), pelin (Artemisia vulgaris), soğan (Allium cepa), dağ kekiği (Satureja montana), Avustralya çay ağacı (Melaleuca alternifolia), rezene (Foeniculum vulgare), zerdeçal (Curcuma longa), limon melisası (Melissa officinalis), nane (Mentha piperita), biberiye (Rosmarinus officinalis), adaçayı (Salvia officinalis), tarçın (Cinnamomum zeylanicum), kekik (Thymus vulgaris), zencefil (Zingiber officinale), okaliptüs (Eucalyptus), sarımsak (Allium sativum) ve karanfil (Syzygium aromaticum) yağları bulunmaktadır (Michalina Adaszyńska-Skwirzyńska ve Danuta Szczerbińska,2007). Esansiyel yağların antimikrobiyal özellikleri iyi bilinmektedir (Kalemba & Kunicka, 2003). Esansiyel yağların antimikrobiyal özellikleri, esas olarak fenoller, aldehitler ve terpenlerden kaynaklanmaktadır; bu bileşikler, bakteri hücre zarlarının bütünlüğünü ve fonksiyonunu bozma yeteneğine sahiptir (Di Pasqua ve diğerleri, 2007).

Kullanılan bir diğer yöntem ise yemlere antioksidan maddelerin ilavesi şeklinde olmaktadır. Antioksidanlar endojen ve eksojen olarak ikiye ayrılmaktadır ve Eksojen antioksidanlar ise genellikle gıdalar yoluyla alınan doğal ve sentetik antioksidanları kapsamaktadır. Eksojen antioksidanlara örnek olarak çinko, bakır, selenyum, likopenler verilirken endojen antioksidanlara ürik asit, melatonin ve albümin örnek verilmektedir (Gümüş ve Küçükersan,

2017). Tercih edilen önemli antioksidanlar arasında E vitamini, askorbik asit, β-karoten, glutatyon, karnozin, homokarnozin ve anserin gibi doğal antioksidan maddeler sıralanmaktadır (Konyalıoğlu 2001). Kanatlılar, normal şartlar altında vücutta biriken serbest radikalleri antioksidan sistemleriyle etkisiz hale getirebilir. Ancak stres gibi etmenler, serbest radikal düzeylerini artırarak vücudun endojen antioksidan kaynaklarını tükenmesine neden olabilir. Bu durumda, yem rasyonlarında yapılan düzenlemeler oksidatif bozulmayı engelleyebilir ve oksidatif stresin etkilerini azaltabilir. Bu nedenle, kanatlı rasyonlarına antioksidan maddeler veya endojen savunma mekanizmalarını güçlendiren katkı maddeleri eklenebilir (Çelebi ve ark. 2016).
Bu çalışmanın amacı bu yem katkı maddelerinin broylerler de et kalitesi üzerine etkilerinin araştırıldığı çalışmalar üzerine bibliometrik analiz sunmaktır. Bibliyometrik analiz, belirli bir konuya ilişkin araştırma yayınlarını istatistiksel ve matematiksel olarak incelenmesi sonucunda meydana gelmektedir (Demir ve ark., 2022). Literatürde bulunan çalışmaların geniş çerçeve de incelenmesi ve değerlendirilmesi için bibliometrik analiz kullanılabilmektedir. (Demir ve ark., 2024). Sosyal bilimler alanından scopus en geniş arama motoru olduğu için bibliyometrik analiz için tercih edilmiştir. (Martin- Martin A., 2018)

Çalışmanın Önemi Ve Amacı

Bu çalışma ülkemizdeki artan tavuk eti tüketimine bağlı olarak üretimde iyileştirilmelere gidilme, daha yüksek kalite ve verim hedefleme sonucunda üretimde kullanılan yem katkı maddelerinin bibliometrik inceleme olarak analiz edilmesini hedeflemektedir. Son zamanlarda yem katkı maddeleri alanındaki araştırma çalışmalarının arttığı fark edilmiştir. Bu analiz yem katkı maddelerinin et kalitesiyle ilişkisinin önemini yapılan çalışma sayıları ve verilerle ortaya koymaya çalışmaktadır. Yem katkı maddelerinin et kalitesi üzerine etkilerinin hem hayvan refahı açısından hem de tavuk gelişimi sürecinde olumlu etkilerinin görülmesinin bu alanda çalışmaları arttırdığı düşünülmektedir. Bibliometrik analiz sonuçlarıyla beraber ortaya konan veriler ile broyler yetiştiriciliğinde yeni çalışmalara katkı sunulması beklenmektedir.

Araştırmanın Soruları

Bu çalışma bibliometrik analiz ile araştırmaların yoğunlaştığı ülke, en çok atıf alan makaleler, önemli yazarlar ve yıllara göre yayın durumlarının geniş bir alanda incelenmesiyle oluşmuştur. Bu bağlamda bu analiz çalışmasında şu soruların cevaplarına ulaşmak mümkündür:

- Q1: Broiler yetiştiriciliğinde yem katkı maddelerinin et kalitesi üzerine etkisi hakkında en çok yayın yapan ülke ve yazar hangisidir?
- Q2: Broiler yetiştiriciliğinde yem katkı maddelerinin et kalitesi üzerine etkisi hakkında yıllara göre yayın analizi nasıldır?
- Q3: Broiler yetiştiriciliğinde yem katkı maddelerinin et kalitesi üzerine etkisi hakkında en çok yayın yapan dergiler hangileridir?
- Q4: Broiler yetiştiriciliğinde yem katkı maddelerinin et kalitesi üzerine etkisi hakkında yapılan araştırmalarda en çok aranan anahtar kelime nedir?
- Q5: Broiler yetiştiriciliğinde yem katkı maddelerinin et kalitesi üzerine etkisi hakkında öne çıkan üniversiteler hangileridir?
- Q6: Broiler yetiştiriciliğinde yem katkı maddelerinin et kalitesi üzerine etkisi hakkında en çok atıf alan makale ve yazar hangisidir?

Bu yazı aşağıdaki gibi organize edilmiştir. Bölüm 2 ‘de literatür taramasının analizi bulunmaktadır. Bölüm 3’te Materyol ve metod kısmından bahsedilmiştir. Bölüm 4’te çalışmanın bibliometrik analizinin ana bilgileri, araştırma konuları, araştırma boşlukları sunulmuştur. Çalışma tartışma ve sonuç bölümlerinin açıklamaları ile sonlanmaktadır.

Çalışmanın Katkıları

Bu bibliyometrik analiz, broyler yetiştiriciliğinde yem katkı maddelerinin et kalitesi üzerine etkilerinin incelenmesi üzerine yapılmış bir çalışmadır. Yem katkı maddeleri ve broyler et kalitesindeki değişimler arasındaki ilişkiye bağlı olarak bu alanda önemli katkılar sunması hedeflenmektedir. Literatürdeki çalışmaların taranması ile oluşturulan bu çalışma, bibliyometrik analiz yöntemiyle broyler yetiştiriciliği alanında yem katkı maddelerinin etkilerinin geniş kapsamda incelenmesiyle bir değerlendirilme sunulmuştur. Bu kapsamda hangi yem katkı maddeleriyle daha önce çalışıldığı, güncel olarak çalışılmaya devam eden yem katkı maddeleri ve broyler gelişiminde analiz verileri çalışmada verilerle gösterilmiştir. Bu verilere dayanarak gelecek zamanda yapılacak olan çalışmalarda daha önce çalışılmamış, son zamanlarda popüler olan konular ile ilgili yol gösterici olabileceği ve yeni çalışmalara rehberlik edebileceği düşünülmektedir.

Araştırma Boşlukları

Broyler yetiştiriciliğinde yem katkı maddelerinin kullanımı üzerine yapılan araştırmalarda aşağıdaki temel boşluklar tespit edilmiştir Bunlardan ilki 'Yem Katkı Maddelerinin Çalışma Mekanizmalarının Detaylı Olarak İncelenmesi' konusudur. Birçok çalışma yem katkılarının büyüme performansı ve et kalitesi üzerindeki etkilerini ele almıştır. Ancak, bu katkı maddelerinin moleküler düzeydeki etkileri ve bağırsak mikrobiyotasındaki değişimler gibi mekanizmaların tam olarak aydınlatılmadığı görülmektedir. Diğeri ise 'Uzun Vadeli Etkilerin İncelenmesi' konusudur. Yem katkı maddelerinin kısa zaman diliminde olumlu etkiler gösterdiği bilinmekle birlikte, uzun süreli kullanımının sağlık ve besi performans üzerindeki etkileri hakkında yeterli veri olmadığı görülmüştür. Özellikle bu konu içeriğinde katkı maddelerinin kalıntı oluşturma konusunda etkileri halen araştırılmaktadır. 'Katkı Maddeleri Kombine Kullanıldığında Ortaya Çıkan Etkiler' diğer boşluklardan biridir. Farklı yem katkı maddelerinin sinerjik ya da antagonistik etkileri üzerine yapılan araştırmalar sınırlıdır. **'**İklim ve Çevresel Faktörlerin Etkileri 'incelendiğinde çoğu çalışma kontrollü laboratuvar koşullarında gerçekleştirildiği görülmüştür. Farklı iklim şartlarında, özellikle sıcaklık stresinin yoğun olduğu bölgelerde katkı maddelerinin etkinliğini inceleyen araştırmalar yeterli görülmemiştir. Son olarak görülen boşluk ise 'Alternatif Yem Maddeleri ile Etkileşim**'** konusu olmuştur. Son zamanlarda sık kullanılmaya başlanan yem katkı maddelerinin mevcut katkı maddeleri ile etkileşimleri henüz yeterince araştırılmamıştır. Bu eksikliklerin giderilmesi, broyler yetiştiriciliğinde yem katkı maddelerinin daha etkili ve sürdürülebilir bir şekilde kullanılmasını sağlayabilir.

Literatür Taraması

Yapılan literatür taramasında yazarların bildiği kadarıyla 'Broyler Tavuklarında Yem Katkı Maddelerinin Et Kalitesi Üzerine Etkilerinin Bibliometrik Analizi' başlıklı çalışmaya benzer çalışmalara rastlanılmamış olup literatüre katkı sağlayacağı düşünülmektedir.

Tavuk yetiştiriciliğinde büyüme hızını artırmak için antibiyotiklerin yaygın olarak kullanılması, bu uygulamanın sağlık üzerindeki olumsuz etkileri nedeniyle dünya genelinde birçok ülkede yasaklanmıştır. Bu yasakların ardından, antibiyotiklerin yerini alabilecek alternatif katkı maddelerinin araştırılması hız kazanmıştır. Wickramasuriya ve arkadaşlarının (2024) bibliyometrik analizi, tavuk yetiştiriciliğinde antibiyotik büyüme destekleyicilerine alternatif ürünlerin araştırılmasında ABD'nin lider ülke olduğunu ve broyler tavukları üzerine yapılan çalışmaların ön planda olduğunu göstermektedir. Ayrıca, probiyotikler ve fitogenetikler, bu alandaki en çok araştırılan konular arasında yer almıştır.

Cesari ve arkadaşları (2024), broiler tavukları ile ilgili refah çalışmaları üzerine bir metin madenciliği analizini sunmuşlardır. Bu çalışma, broyler tavuklarının refahını artırmak için yapılan çalışmaların son on yılda artış gösterdiğini ve bu çalışmaların kesim yöntemleri gibi çeşitli parametreleri kapsadığını vurgulamaktadır. Benzer şekilde, Dinasarki ve arkadaşları (2024), broyler ürünlerinin kalitesinin pazarlama performansı üzerindeki etkisini incelemiş ve yemden yararlanma performansı ile besin takviyelerinin pazarlama stratejilerini iyileştirebileceğini belirtmişlerdir.

Broyler tavuklarının büyüme performansını etkileyen faktörler, dünya genelindeki pek çok çalışmanın odak noktası olmuştur. Wu ve arkadaşları (2024), broyler tavuklarının et kalitesini iyileştirmek için yeşil ceviz kabuğu ekstraktını içeren yemlerin etkisini incelemiş ve bağırsak sağlığı ile et gelişimi üzerinde olumlu etkiler gözlemiştir. Benzer şekilde, Banday ve arkadaşları (2024) Malva sylvestris yaprak tozu ilavesinin broyler tavuklarındaki büyüme performansı, bağışıklık düzeyi ve bağırsak florası üzerinde olumlu etkiler yarattığını tespit etmişlerdir.

Sıcaklık stresinin kümes hayvanları üzerindeki etkisi de önemli bir araştırma alanı olmuştur. Uyanga ve arkadaşları (2023) sıcaklık stresinin broyler tavuklarındaki büyüme performansını, bağırsak florasını ve et kalitesini olumsuz etkilediğini, gelecekte refah çalışmalarına ve et kalitesini artırmaya yönelik katkı maddelerinin kullanımının artacağını öngörmüşlerdir. Risk yönetimi ve teknoloji kullanımı da kümes hayvancılığı sektöründe önemli bir yere sahiptir.

Sharif ve arkadaşları (2023), 2002-2022 yılları arasında kümes hayvancılığındaki riskler ve teknoloji kullanımına yönelik yapılan çalışmalarda bir artış gözlemiş ve teknolojinin bu riskleri azaltmadaki öneminin giderek arttığını belirtmişlerdir. Yardibi ve Fırat (2021) ise, hayvansal üretim alanında büyüme performansının araştırılma derecesini incelemiş ve 2010 yılında en fazla yayın yapılmış yıl olduğunu, Çin'in en çok çalışmayı gerçekleştiren ülke olduğunu ortaya koymuşlardır. Çalışma, özellikle broyler tavukları, besin sindirimi ve et kalitesi parametrelerine odaklanmıştır. Mafruchati ve arkadaşları (2022), broyler tavuk embriyolarının büyümesini etkileyen hastalıklar ve virüsler üzerine yapılan çalışmaları analiz etmiş ve genetik faktörler ile virüslerin bu alandaki en önemli araştırma konuları olduğunu belirtmişlerdir.

Dinasarki ve arkadaşları (2024) çalışmasında, broyler tavuklarındaki kalite unsurlarının pazarlama stratejileri üzerindeki etkisi ele alınmıştır. Bu çalışma, Scopus veri tabanı kullanılarak 'broyler 've 'pazarlama' anahtar kelimeleriyle yapılan analiz sonuçlarına dayanır. Araştırma, broyler tavuklarının üretim süreçlerinde fiziksel koşulların, yem verimliliğinin ve besin takviyelerinin pazarlama performansını nasıl etkilediğini incelemektedir. Özellikle, kümesin fiziksel durumlarının iyileştirilmesi, yem verimliliği ve uygun besin takviyeleri kullanımının

pazarlama performansını artırabileceği sonucuna varılmıştır. Bu bulgular, broyler üretim süreçlerinde kalite iyileştirmelerinin pazarlama stratejilerinin başarısı üzerinde doğrudan etkisi olduğunu göstermektedir. Adnan ve arkadaşlarının (2024) yaptığı başka bir çalışma, sorgum araştırmalarındaki küresel eğilimleri incelemektedir. Sorgum, geleneksel olarak yem bitkisi olarak bilinse de son yıllarda farklı uygulama alanlarında da giderek daha fazla tercih edilmektedir. Çalışma, Scopus veri tabanında yapılan analizlere dayanarak, sorgumun genetik ekspresyon, bitki stres faktörleri, tahıl verimliliği, biokütle üretimi ve
metabolizma üzerine yapılan araştırmaları tartışmaktadır. Bu çalışmanın biokütle üretimi ve yem verimliliği konularında önemli katkılar sunması beklenmektedir. Özellikle, sorgumun sanayi ve tarım sektörlerinde artan kullanımının, biokütle üretimi ve yem verimliliği alanındaki araştırmalara nasıl katkı sağlayabileceği vurgulanmıştır.

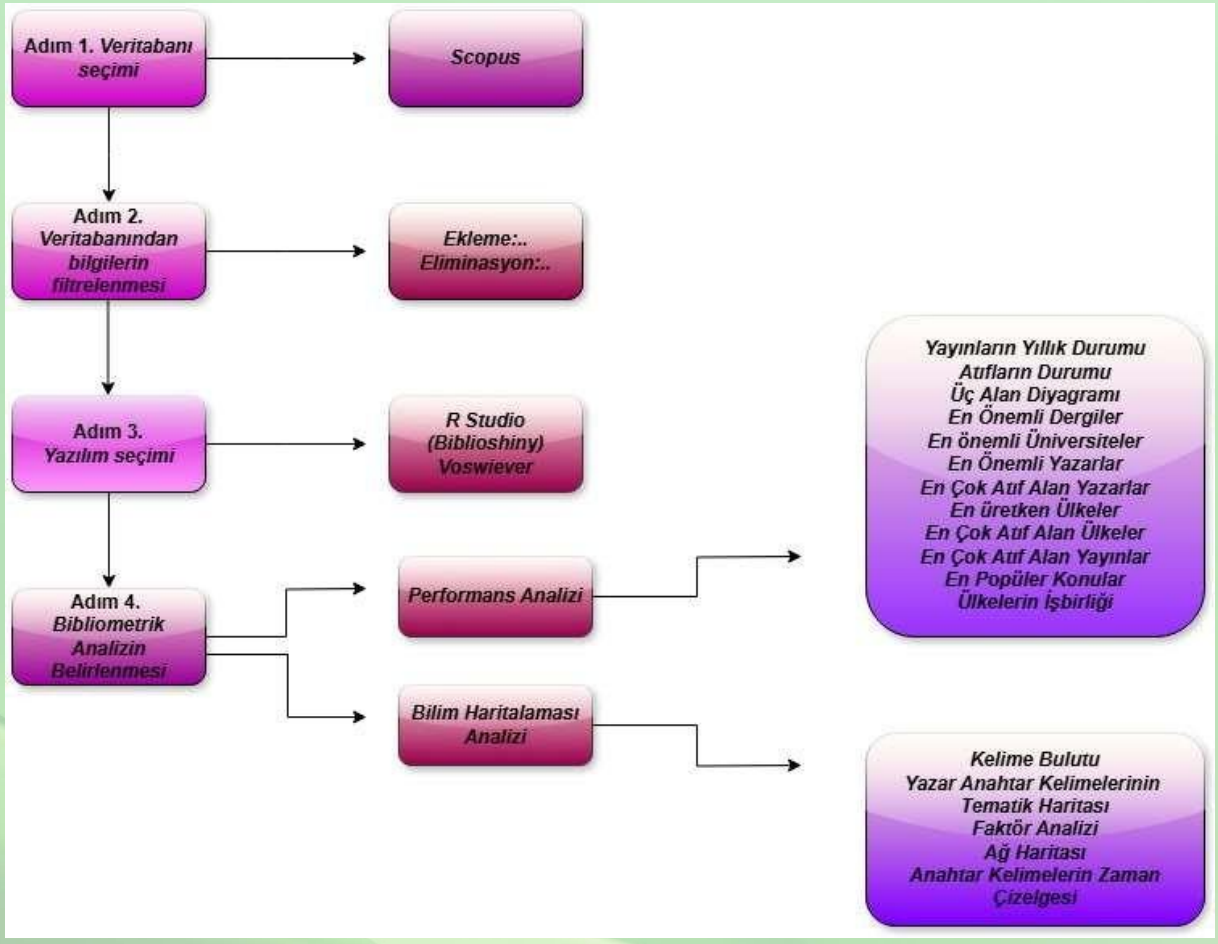
Bu literatür taraması, tavuk yetiştiriciliğinde antibiyotiklerin yerine geçebilecek alternatiflerin ve broyler tavuklarının büyüme performansını artırmaya yönelik katkı maddelerinin araştırıldığını göstermektedir. Ayrıca, broyler tavuklarının refahı, et kalitesi ve sıcaklık stresi gibi konular da günümüzdeki araştırmaların odak noktasını oluşturmaktadır. Bu alandaki çalışmalar, beslenme, genetik ve çevresel faktörlerin yanı sıra, teknolojinin etkin kullanımı ile de daha verimli ve sürdürülebilir tavuk yetiştiriciliğine katkı sağlamayı hedeflemektedir. Tablo 1'de literatür taramasında kullanılan bibliometrik analizlerin tablo üzerinde gösterimi verilmiştir.

Tablo 1. Broiler Yetiştiriciliğinde Yem Katkı Maddelerinin Et Kalitesi Üzerine Etkilerinin Bibliyometrik Analizi

Yazarlar	Yıl	Anahtar Kelimeler	Zaman Aralığı	İncelenen Yayın Sayısı	Veri Tabanı	Kullanılan Yazılımlar
Mafruchati ve ark.	2024	Chicken, Embryo, Food security, Illness, Immunology	2008-2022	1348	Scopus	Biblioshiny, VOSviewer
Dinasark ve ark	2024	Broiler marketing strees management; Industry regulation, Retailer	1963-2023	250	Scopus	VOSviewer
Adnan ve ark.	2024	Bibliometric analysis, content analysis, feed, food, bioenergy, sorghum, co-occurrence analysis	2019-2023	8,856	Scopus	VOSviewer
Wickramasuriva ve ark.	2024	Alternative to the antibiotic growth promoter, poultry, global trend, publication	2009-2022	2038	Scopus , Web of Science/InCites, and Dimensions	Rayyan
Singhal ve ark.	2024	Environmental enrichment, brain, rodents, hippocampus, learning, memory, behavior, cogniti	1967-2024	2385	Scopus	VOSviewer, R Studio
Uyanga ve ark.	2023	Bibliometric, chickens, growth performance, heat stress, oxidative stress, VOSviewer	2000-2021	684	Web of Science	VOSviewer
Sharif ve ark.	2023	Poultry farming risk; poultry farming industry bibliometric analysis; Harzing's Publish or Perish, VOSviewer	2002-2022	477	Scopus	VOSviewer
Cui ve ark.	2023	Farm animal welfare; China, research trends; research hotspots, research frontiers Bibliometric analysis;	2008-2023	1215	Web of Science	CiteSpace
Oliveira ve ark.	2023	Embryos; feeding in ovo, hatching eggs; poultry production, VOSviewer	1985-2023	242	Scopus	VOSviewer

Materyal Ve Yöntem

Bu çalışma bibliyometrik analiz yöntemi kullanılarak yapılmıştır. Bibliyometrik analiz, bilimsel yayınların nicel analizini ve değerlendirilmesini ele alan bir disiplindir. Bu yöntem, belirli bir konu üzerindeki yayınların filtreleme yöntemleri kullanılarak birbirleriyle ile iletişim ve etkileşimlerini incelenmesinde kullanılır. (Demir ve ark., 2024a). Çalışmada, bu alanda yapılan yayınların dağılımı, en çok atıf yapılan makaleler, en çok kullanılan kelimeler en önemli yazarlar, en çok yayın yapan dergiler, ülkelerin iş birlikleri ve anahtar kelimeler değerlendirilmiştir Bibliyometrik analiz sayesinde bu zamana kadar yapılmış çalışmalar ışığında yapılacak olan yeni çalışmalara yol gösterici olabileceği hedeflenmektedir. Buna bağlı olarak broyler yetiştiriciliğinde yem katkı maddelerinin et kalitesi üzerine etkileri alanında görülebilecek araştırma boşlukları da tespit edilebilecektir.
Çalışmanın verilerine ulaşmak için Scopus veritabını kullanılmıştır. Makaleler arasında bazı filtreleme yöntemleri yapıldıktan sonra Biblioshiny paket programı ve Vosviewer paket programı ile veriler sırası ile incelenmiş ve çalışma yapılmıştır. Bu çalışmanın sırası aşağıdaki şekilde de gösterilmiştir. Aşağıda verilen Şekil 1 'de broiler', 'feed', 'supplements', 'meat quality' anahtar kelimeleri ile ilgili yapılan araştırmanın adımlarını içeren bibliyometrik analiz akış diyagramı verilmiştir.



Şekil 1. Bibliyometrik analiz akış diyagramı

Bu çalışmada, veri kaynağı olarak uluslararası bir platform olan "Scopus" tercih edilmiştir. Scopus, sosyal bilimler alanında en kapsamlı veri tabanlarından biri olarak kabul edilmekte ve karşılaştırmalı çalışmalar için birçok yazar tarafından yaygın bir şekilde kullanılmaktadır (Bashar ve ark., 2022; Hassan ve ark., 2022; Singh ve Bashar, 2021). Her ne kadar WoS ve Scopus veri tabanları temel özellikler açısından benzerlik gösterse de Scopus sosyal bilimler literatürünü kapsamlı bir şekilde indekslemesiyle öne çıkmaktadır (Ferreira ve ark., 2021). Ayrıca Scopus, dergi isimleri, h-indeks değerleri, atıf analizleri gibi bibliyometrik analizler için gerekli birçok fonksiyonu barındırmaktadır (Haque ve ark., 2020). Aşağıda Verilen Tablo 2'de Scopus veri tabanından alınan verilerin filtrelenmesi gösterilmiştir.

Tablo 2. Scopus veri tabanındaki verilerin filtrelenmesi

DAHİL OLANLAR	Anahtar kelimeler : Broiler', 'feed', 'supplements', 'meat quality' Belge Türü : Makale Yayın Dili : İngilizce Yayın Şekli : Dergi Yayın Yılı: 2004-2024
DAHİL OLMAYANLAR	Ön baskı web sitelerinde yayınlanan inceleme ve konferans bildirileri, kitap bölümleri, makaleler veya incelemelerin yanı sıra yorumlar, başyazılar ve mektuplar

Broiler', 'Feed', 'Supplements', 'Meat Quality' İle İlgili Çalışmaların Bibliometrik Analiz Sonuçları

Çalışmanın ana kütlesini 536 doküman oluşturmaktır. Çalışmada 2004-2024 yılları arasında 'broiler, supplements, meat quality, chicken' anahtar kelimeleri ile filtrelemeler sonucunda örneklem sayısı 487 olmuştur.

Performans Analizi

Aşağıdaki Şekil 2'de bibliyometrik analizin ana bilgilerinden oluşan tablo verilmiştir. 2004-2024 yılları arasında yapılan çalışmalara 119 dergide ve 487 makalede ulaşılmıştır. 'Broiler', 'feed', 'supplements', 'meat quality' anahtar kelimeleri ile 2160 yazar çalışma yapmış ve bu yazarların 5'i tek başına literatüre katkı sağlamıştır. Yayınların yıllık büyüme oranı % 16,89, uluslararası yazarların iş birliği %22,38 ve bir eserin ortalama yaşı 4,95 yıl olarak tespit edilmiştir.



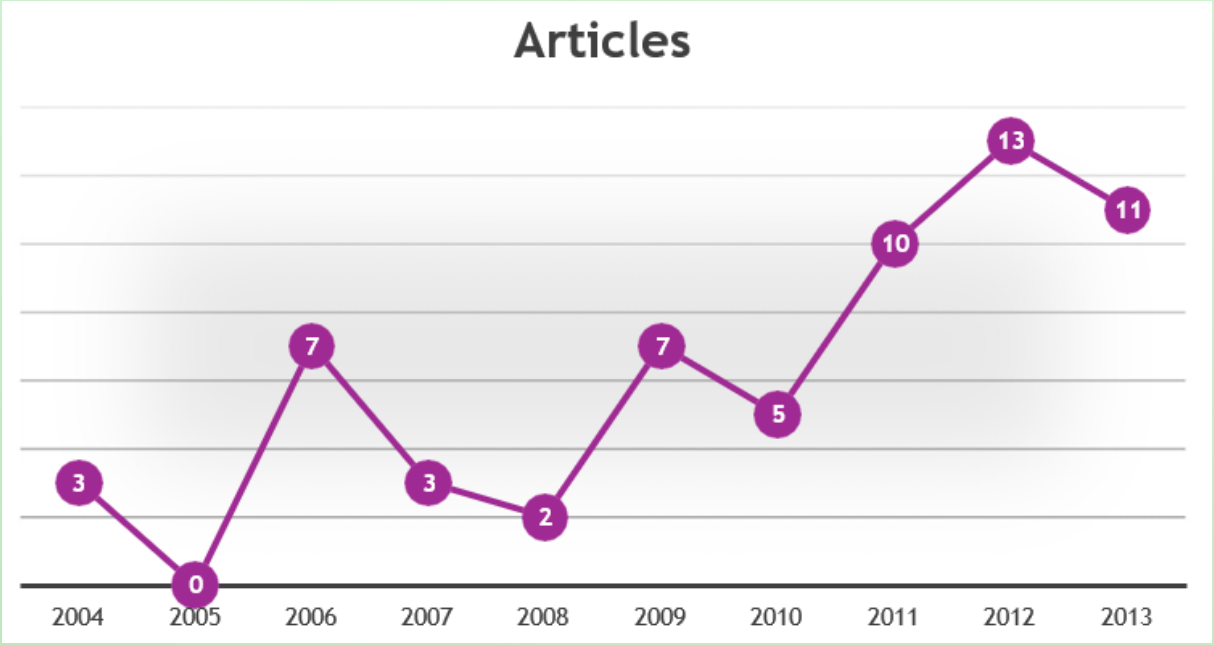
Şekil 2. Ana Bilgiler

Yayınların Yıllık Durumu

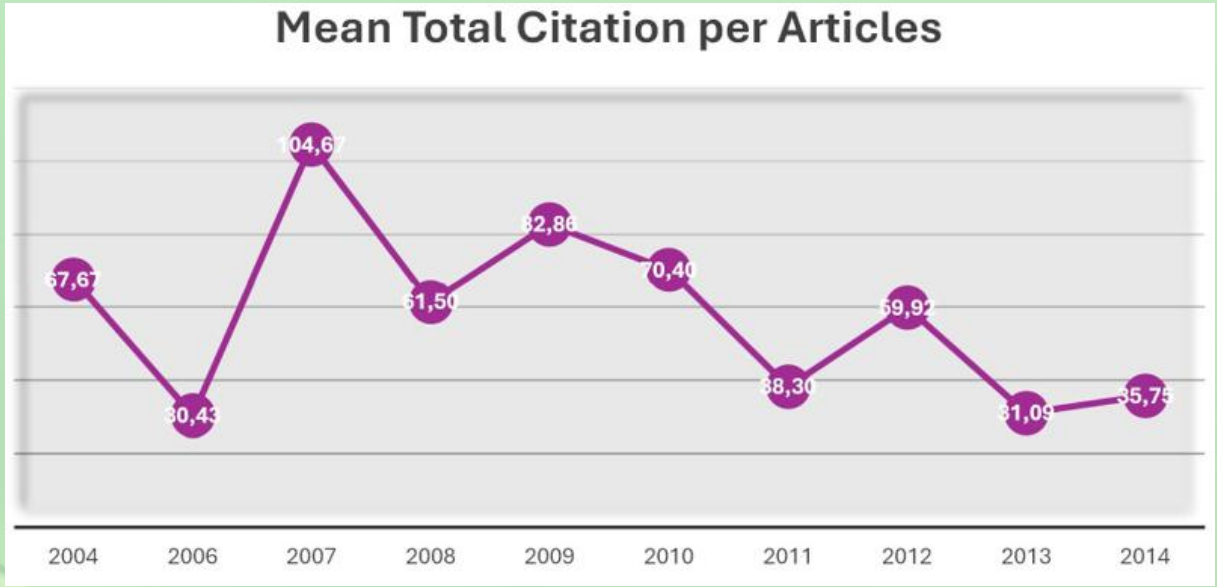
Yayınların yıllık durumuna göre yayımlanma sayıları aşağıdaki Şekil 3'te verilmiştir. Şekil 3 'de 2004-2024 zaman aralığında 2013 yılında 11 makale, 2012 de 13 makale 2011 yılında 10 makalenin literatüre kazandırıldığı görülmüştür.

Atıfların Durumu

Aşağıda verilen Şekil 4 'te yılları göre makalelere yapılan atıf sayıları gösterilmiştir. Yayınlara yapılan atıfların yıllık durumları grafiğe göre değişen bir eğilim göstermektedir. 2004 yılında yayınlara % 67,67 atıf yapıldığı görülürken 2014 yılında %37,75'lik bir atıf oranının mevcut olduğu görülmüştür. Bu değişimin nedeni 'broiler', 'feed', 'supplements', 'meat quality' anahtar kelimeleri ile bu konuyla ilgili yapılan araştırmaların değişiklik gösterdiği görülmektedir.



Şekil 3. Yayınların Yıllık Durumu



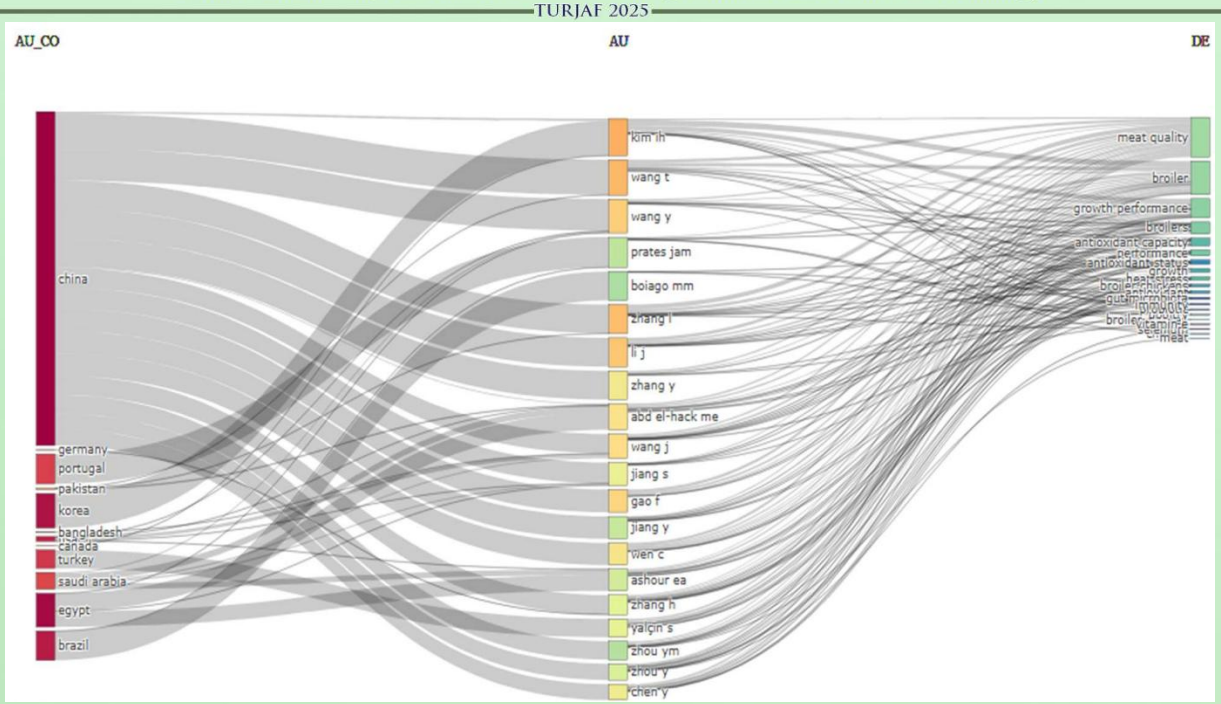
Şekil 4. Atıfların Durumu

Üç Alan Diyagramı

Aşağıda verilen Şekil 5'te Sankey diyagramı olarak da literatüre geçen üç alan diyagramı verilmiştir. Sankey diyagramı olarak da bilinen bu üç alan diyagramında üç parametre karşılaştırılmıştır. Biblioshiny ara yüzünün sağladığı avantaj ile yazar, ülke ve anahtar kelime parametreleri çalışılmıştır. Diyagramdaki dikdörtgenlerin büyüklüğü analize tabi olan parametrenin önemini göstermektedir. En önemli ülke Çin, en önemli yazar Kim ih, en önemli kelime 'meat quality'dir.

En Önemli Dergiler

Aşağıda oluşturulan Tablo 3'te broiler', 'feed', 'supplements', 'meat quality' anahtar kelimeleri ile ilgili araştırma yapan ve yayımlanan en önemli dergiler verilmiştir



Şekil 5. Üç Alan Diyagramı

Tablo 3. En Üretken Dergiler

Sources	Articles
POULTRY SCIENCE	156
BRITISH POULTRY SCIENCE	46
TROPICAL ANIMAL HEALTH AND PRODUCTION	18
ANIMALS	16
JOURNAL OF THE SCIENCE OF FOOD AND AGRICULTURE	16
JOURNAL OF ANIMAL PHYSIOLOGY AND ANIMAL NUTRITION	15
ANIMAL	13
JOURNAL OF ANIMAL SCIENCE	11
BIOLOGICAL TRACE ELEMENT RESEARCH	10
ANIMAL SCIENCE JOURNAL	7

En Önemli Üniversiteler

Aşağıda verilen Tablo 4'te araştırmaya dahil olan en önemli üniversiteler sırasıyla verilmiştir. Birinci sırada 'Nanjıng Agricultural University' 191 ile yer almaktadır. 'Dankook University' 96 makale ile ikinci sırada, 'Institute Of Animal Science' ise 59 makale ile üçüncü sırada yer almaktadır.

Yapılan çalışmada en önemli yazarlar arasında 29 makale ile 'Kim IH.' birinci sırada, 'Wang T.' 14 makale ile ikinci sırada, 'Zhang L.' 13 makale ile üçüncü sırada yer almaktadır. Tablo 5 'de bulunan veriler incelendiğinde en çok atıf alan yazarlar arasında Kim, Ih. 15 makale 602 atıfla birinci sırada, Park, j.h. 6 makale 280 atıf sayısı ile ikinci sırada, Fontes, c.m.g.a 4 makale 272 atıf ile üçüncü sırada yer almaktadır.

Tablo 4. En Önemli Üniversiteler

Affiliation	Articles
NANJING AGRICULTURAL UNIVERSITY	191
DANKOOK UNIVERSITY	96
INSTITUTE OF ANIMAL SCIENCE	59
UNIVERSIDADE DE LISBOA	53
ZAGAZIG UNIVERSITY	43
CHINA AGRICULTURAL UNIVERSITY	42
HUNAN AGRICULTURAL UNIVERSITY	41
KING SAUD UNIVERSITY	39
UNIVERSITY OF ILORIN	34
ZHEJIANG UNIVERSITY	33

Tablo 5. En Önemli Yazarlar

Authors	Articles	Articles Fractionalized
KIM IH	29	9,22
WANG T	14	2,14
ZHANG L	13	2,19
LI J	12	1,98
WANG Y	11	1,39
GAO F	10	1,66
WANG J	10	1,77
ABD EL-HACK ME	9	1,19
WEN C	9	1,37
ZHANG Y	9	1,20

En Çok Atıf Alan Yazarlar

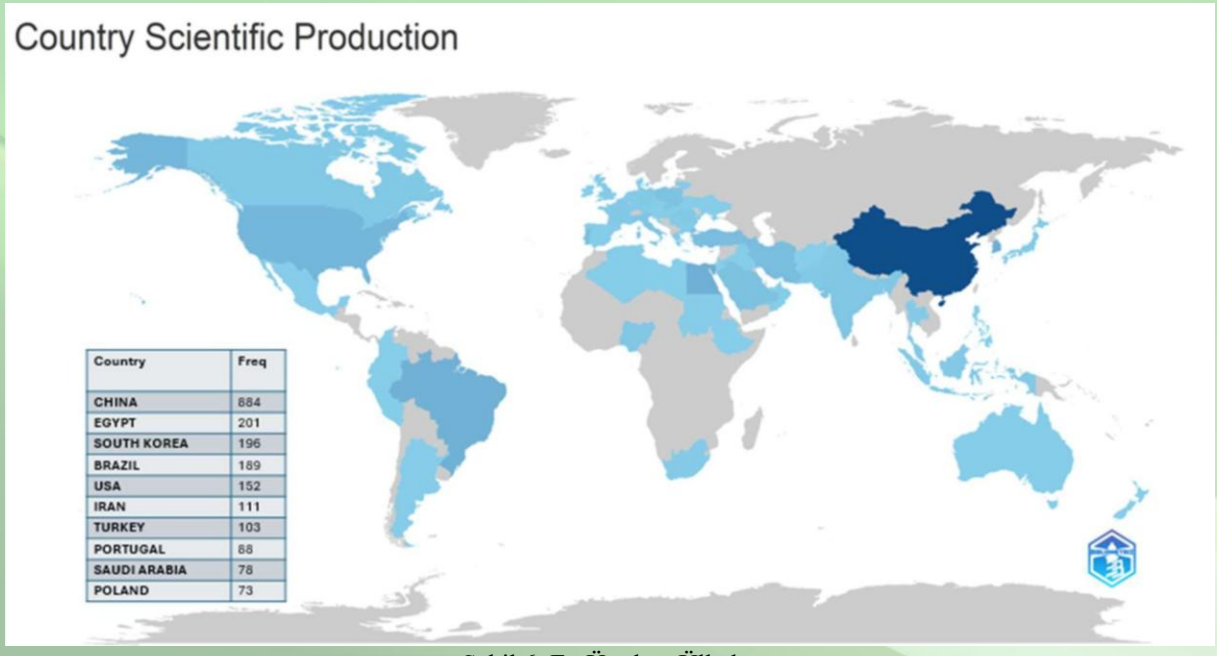
Aşağıda verilen Tablo 6 'te en çok atıf alan yazarlar ve yayımlanan makale sayıları sırası ile verilmiştir.

Tablo 6. En Çok Atıf Alan Yazarlar

Yazar	Makale	Atıf Sayısı
Kim, ı.h.	15	602
Park, j.h.	6	280
Fontes, c.m.g.a.	4	272
Prates, c.a.m	5	272
Wang, t.	6	260
Gao, f.	6	239
Zhou, y.m.	7	223
Wang, tian	6	222
Zhang, l.	7	220

En Üretken Ülkeler

Aşağıdaki Şekil 6'da broiler, feed, supplements ve meat quality anahtar kelimeleri ile ilgili yapılan çalışmada en çok ürüne sahip olan ülkeler renk dağılımı ile gösterilmiştir. Buna ek olarak ülkelerin yayın sıklığı ve sırası da sol taraftaki tablo da görülmektedir. Şekil 6' da ülkelerin üretkenliği verilmiştir. Dünya haritasındaki lacivert renk en çok çalışma yapan ülkeleri temsil eder. Mavi ve tonları daha az sayıda çalışma yapan ülkeleri, gri renk ise hiç çalışma yapmayan ülkeleri temsil eder (Demir ve diğerleri,2024'a). Şekil 8 in içindeki tabloya göre Çin 884 makale ile birinci sırada, Mısır 201 makale ile ikinci sırada, Güney Kore 196 makale ile üçüncü sırada yer almaktadır.



Şekil 6. En Üretken Ülkeler

En Çok Atıf Alan Ülkeler

Aşağıda verilen Tablo 7'te en çok atıf alan ülkeler sıralanmıştır. Tablo 7'de görüldüğü gibi Çin 3154 makale ile birinci sırada, Kore 1234 makale ile ikinci sırada, Amerika Birleşik Devletleri ise 725 makale ile üçüncü sırada yer almaktadır.

Tablo 7. En Çok Atıf Alan Ülkeler

Country	Toplam Atıflar
CHINA	3154
KOREA	1234
USA	725
IRAN	599
TURKEY	484
PORTUGAL	269
BRAZIL	246
BELGIUM	221
AUSTRALIA	182
EGYPT	182

En Çok Atıf Alan Makale

Aşağıda verilen Tablo 8'da en çok atıf alan makaleler, yazarları, yayınlandıkları dergiler ve atıf sayıları verilmiştir. Jiang vd.,2007 yılında Poultry Science dergisinde yayınlanan 'Effects of soybean isoflavone on growth performance, meat quality, and antioxidation in male broilers' makalesi 195 atıf alarak ilk sırada yer almıştır. Daha sonra Jung vd., 2010 yılında Meat Science dergisinde 'Effect of dietary mixture of gallic acid and linoleic acid on antioxidative potential and quality of breast meat from broilers' makalesi ile 191 atıf alarak ikinci sırada yer almıştır. Hwangbo vd.,2009 yılında Journal of Environmental Biology isimli dergide yayınlanan 'Utilization of house fly-maggots, a feed supplement in the production of broiler chickens' adlı makale ile üçüncü sırada yer almaktadır.

Tablo 8. En Çok Atıf Alan Makale

Paper	DOI	Total Citations
JIANG ZY, 2007, POULT SCI	10.1093/ps/86.7.1356	195
JUNG S, 2010, MEAT SCI	10.1016/j.meatsci.2010.06.007	191
HWANGBO J, 2009, J ENVIRON BIOL		183
STARČEVIĆ K, 2015, J SCI FOOD AGRIC	10.1002/jsfa.6805	157
MICHIELS J, 2012, POULT SCI	10.3382/ps.2011-01585	151
CHOCT M, 2004, BRIT POULT SCI	10.1080/00071660400006495	144
DELLES RM, 2014, POULT SCI	10.3382/ps.2013-03682	121
LIU X, 2012, ASIAN-AUSTRALAS J ANIM SCI	10.5713/ajas.2011.11334	120
PONTE PIP, 2008, POULT SCI	10.3382/ps.2007-00147	115
SEVCIKOVA S, 2006, CZECH J ANIM SCI	10.17221/3964-cjas	115

Kelime Bulutu

Şekil 7'de çalışmalarda en çok kullanılan kelimelerden oluşan kelime bulutu verilmiştir. Şekil 7 'de araştırmalarda en çok kullanılan kelimelerin kullanım sıklığın yazı büyüklüğüyle orantılı olarak görülmektedir. Buna göre en çok kullanılan kelimeler; diet, chickens, animal feed, dietary supplement ve meat olmuştur.

Popüler Konular

'Meat' kelimesi 2017 yılının birinci çeyreğinde, 2020'in ikinci çeyreğinde ve 2022' in üçüncü çeyreğinde 684 kere kullanılarak önemli kelime olmuştur. 'Diet' kelimesi 2018 yılının birinci çeyreğinde, 2020 yılının ikinci çeyreğinde ve 2023 yılının üçüncü çeyreğinde 588 kere kullanılarak ikinci sırada yer almaktadır. 'Male' kelimesi ise 2017 yılının ilk çeyreğinde, 2020 yılının ikinci çeyreğinde ve 2023 yılının üçüncü çeyreğinde 477 kere kullanılarak üçüncü sırada yer almıştır. 'Gallus gallus' kelimesi 2024 yılı itibariyle halen aktif olarak kullanılmaktadır. Aşağıdaki Tablo 9'de bu alanda tercih edilen popüler konuların yıllara göre sıklığı verilmiştir.

Yazar Anahtar Kelimelerin Tematik Harita

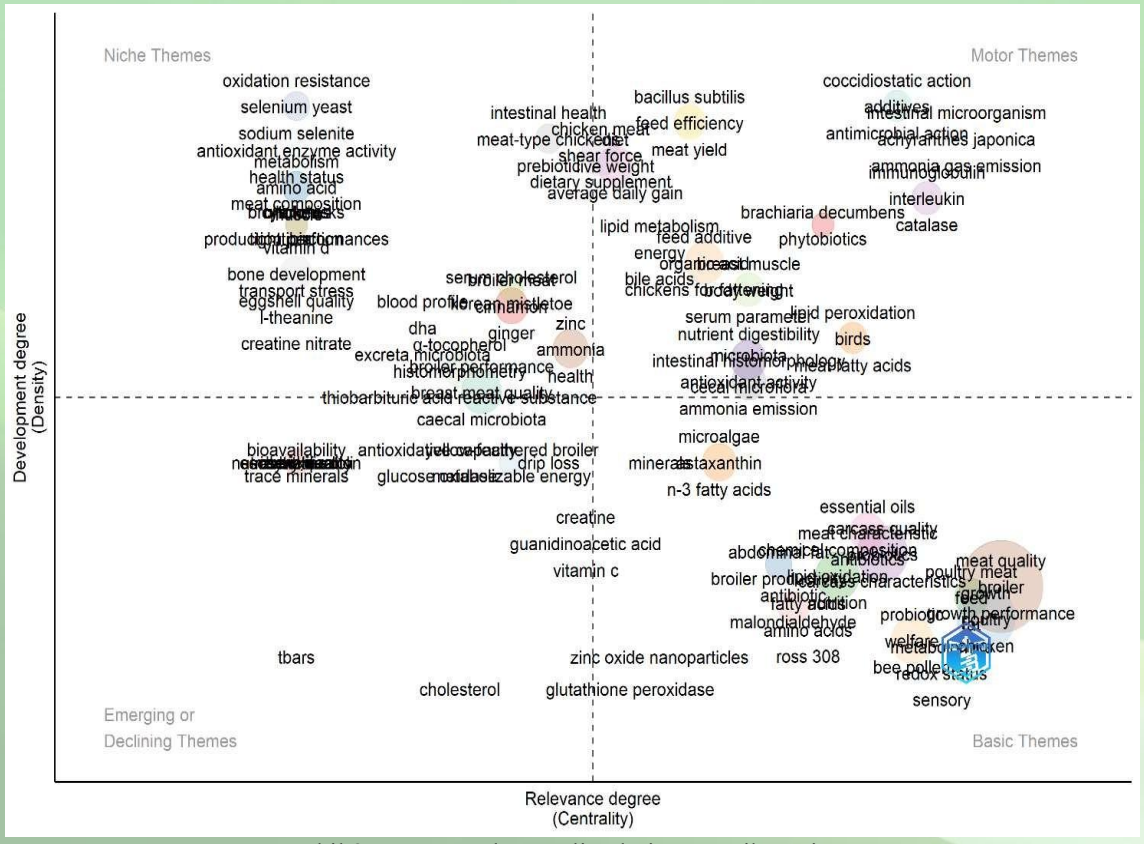
Aşağıda verilen Şekil 8 'de yazarların kullandığı anahtar kelimelerin tematik olarak haritalanmış hali verilmiştir. Şemada yer alan motor tema bölümündeki kümeler, incelenen anahtar kelimenin en temel çalışma alanlarına ait kümeleri göstermektedir. Şemanın temel tema bölümündeki kümeler ise ilgili anahtar kelimenin temel bir yapıda olduğunu ve dönüşüm geçirdiğini, diğer bir deyişle, gelişimini sürdüren kümeleri ifade etmektedir.



Şekil 7. Kelime Bulutu

Tablo 9. Popüler Konular

Term	Frequency	Year (Q1)	Year (Q2)	Year (Q3)
Meat	634	2017	2020	2022
Diet	588	2018	2020	2023
Male	477	2017	2020	2023
Dietary supplement	304	2019	2021	2023
Chicken	278	2015	2019	2021
Veterinary medicine	209	2020	2022	2023
Metabolism	195	2016	2019	2021
Physiology	160	2016	2019	2022
Growth, development and aging	156	2014	2018	2020
Gallus gallus	137	2014	2023	2024

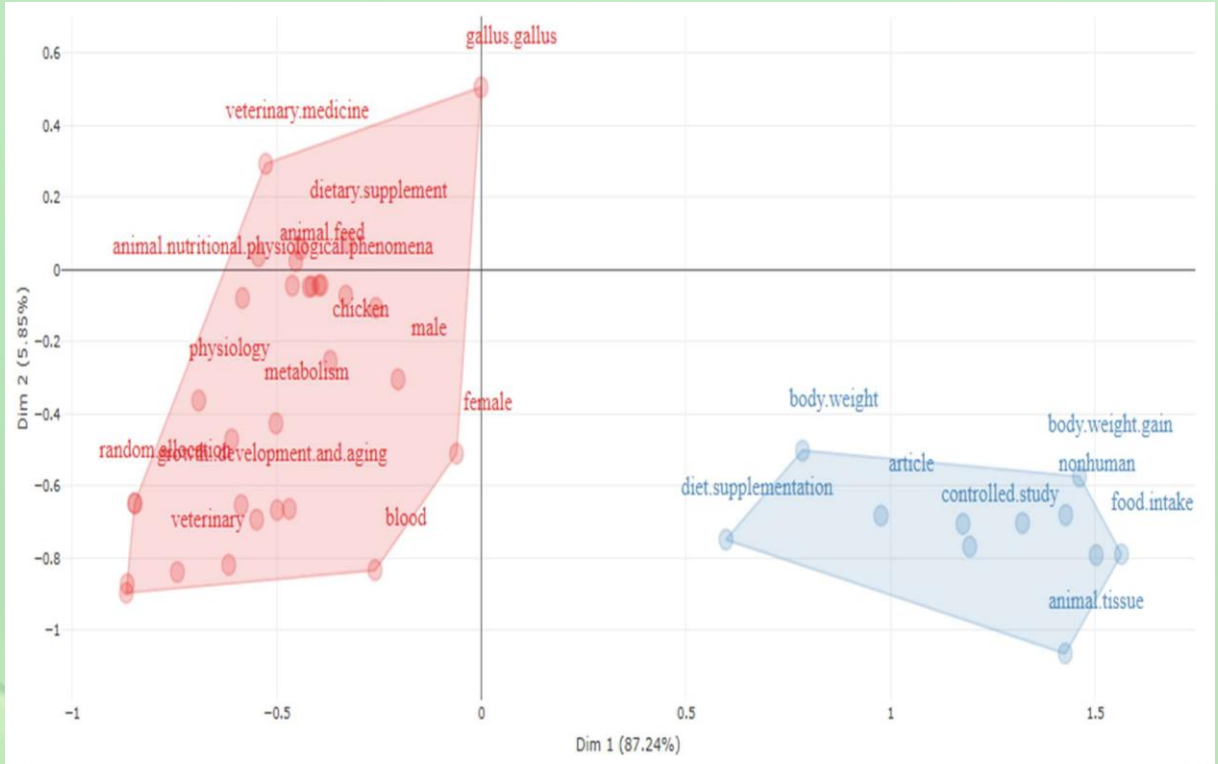


Şekil 8. Yazar Anahtar Kelimelerin Tematik Haritası

Yeni ortaya çıkan veya gerileyen temalar bölümü, yeni ortaya çıkan ya da azalan anahtar kelimeleri gösterirken, niş temalar bölümü ise oldukça fazla sayıda çalışma yapılmış ancak diğer çalışmalardan izole kalmış anahtar kelimeleri içermektedir. Bu nedenle, incelenen anahtar kelimenin hangi bilimsel çalışmalar ile öne çıktığını anlamak için şemanın temel tema ve motor tema bölümlerinin ele alınması gerekmektedir. Motor temada; phytobiotics, meat yield, lipid metabolism, Niche temada; anatioxidant, enzyme activity, creatinin nitrate, amino acid Emergeging temada; cholesterol, bioavabilabity tbars, Basic temada; ise N-3 fatty acids, sensory ve essential oils kelimeleri karşımıza çıkmaktadır.

Faktör Analizi

Aşağıda verilen Şekil 9 'da kullanılan kelime kümeleriyle oluşturulan faktör analiz verilmiştir. Faktör analizi, çok değişkenli veri setlerindeki karmaşıklığı azaltmak ve gizli yapıları ortaya çıkarmak için kullanılan istatistiksel bir tekniktir. Bu yöntem, bir veri setindeki değişkenler arasındaki ilişkileri anlamak ve veri setini daha anlaşılır ve yönetilebilir hale getirmek amacıyla kullanılır. Faktör analizi genellikle faktör yükleri olarak adlandırılan katsayılarla ifade edilir. Faktör yükleri, değişkenlerin hangi faktörlerle ilişkili olduğunu ya da belirli değişkenler arasındaki ortaklığı hangi faktörlerin açıkladığını gösterir. Faktör yüklerine göre kırmızı kümede; blood, veterinary medicine, gallus gallus kelimeleri toplanmıştır. Mavi kümede ise body weight, diet supplementation, animal tissue, food intake kelimeleri yer almıştır.



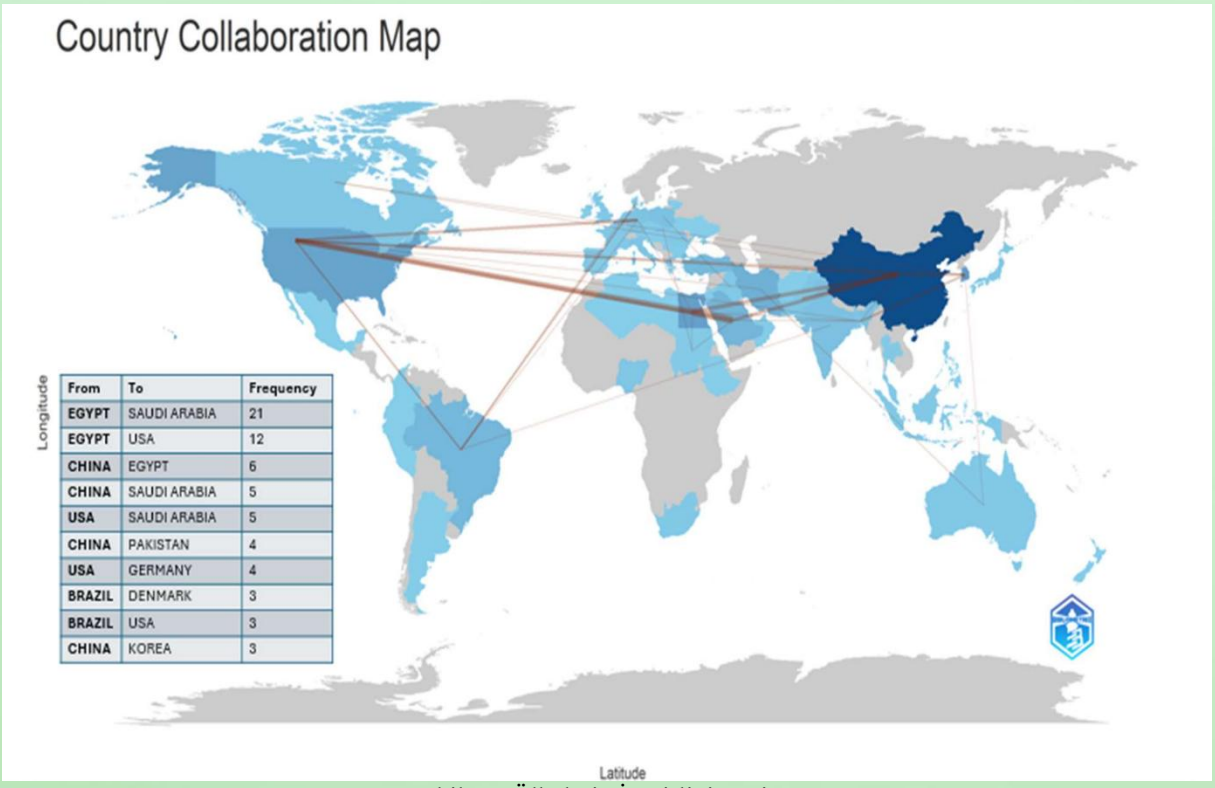
Şekil 9. Faktör Analizi

Ülkelerin İş Birliği Haritası

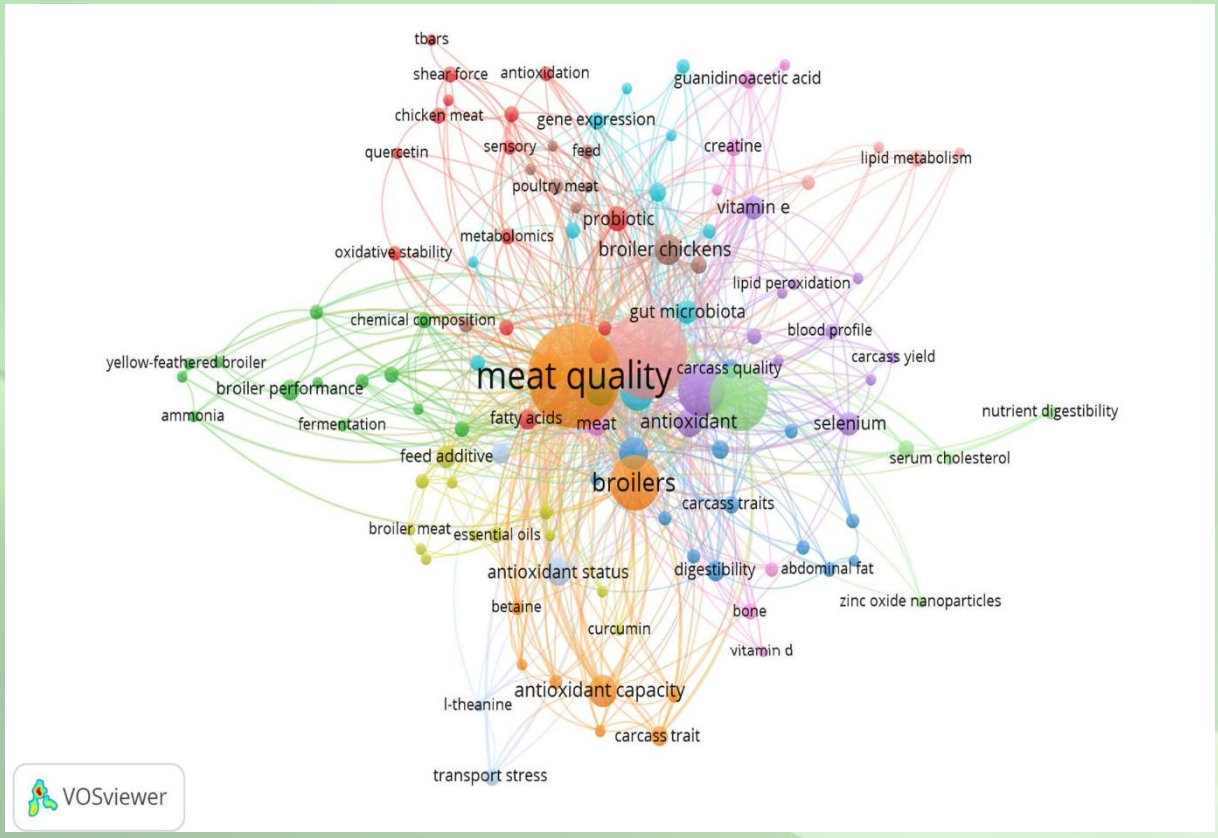
Şekil 10'da yapılan çalışmalarda iş birliği yaparak ilerleyen ülkeler ve bu ülkelerin çalışma sıklığı hem şekil hem tablo olarak verilmiştir. Ülkeler arasındaki iş birliği haritasında kalın kahverengi çizgiler daha çok iş birliği yapıldığını ince kahverengi çizgiler daha az iş birliği yapıldığını göstermektedir. Mısır ve Suudi Arabistan 21 makale ile en çok iş birliği yapan ülkeler arasında birinci sırada yer almaktadır. Mısır ve Amerika Birleşik Devletleri 12 makale ile iş birliği yapan ülkeler arasında ikinci sırayı alırken Çin ve Mısır 6 makale ile üçüncü sırada yer almaktadır. Çin iş birliği yapan ülkeler arasında dünyanın en iyi ülkesi olmuştur.

Ağ Haritası

Aşağıda verilen Şekil 11'de anahtar kelimeler ile oluşturulan ağ haritası verilmiştir. Yukarıda görülen anahtar kelime ağ haritası çalışmasını 12 küme oluşturmuştur. Her renk farklı anahtar kelimeyi temsil etmektedir. Kullanılan çeşitli renklere bakılarak farklı konuların çalışışdığı görülmüştür. Buna göre en önemli üç kelime 'Meat quality, broiler, growth performance' olmuştur.



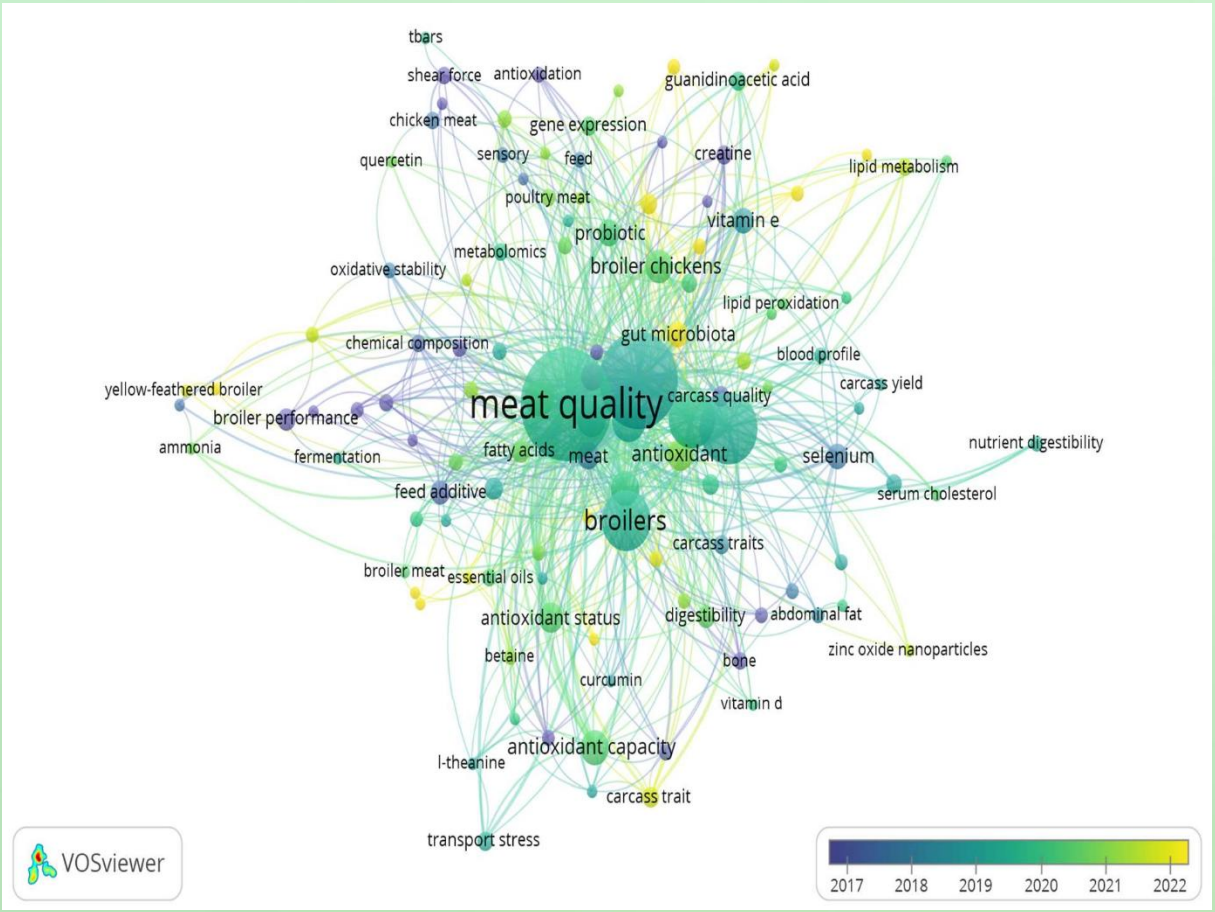
Şekil 10. Ülkelerin İş Birliği Haritası



Şekil 11. Ağ Haritası

Anahtar Kelimelerin Zaman Çizelgesi

Aşağıda verilen Şekil 12'de zaman dağılımına göre kullanılan anahtar kelimeler verilmiştir. Yukarıdaki şekilde feed additive, chicken meat ve feed kelimelerinin daha sık çalışıldığı görülmüştür. Halen literatürde aktif olarak gut microbiata, broiler meat, carcass trait, lipid metobolism, essantial oils gibi kelimeler kullanılmaktadır.



Şekil 12. Anahtar Kelimelerin Zaman Çizelgesi

Tartışma

Scopus veri tabanı üzerinde yapılan bir tarama sonucunda, ilgili zaman aralığında 'broiler', 'feed', 'supplements', 'meat quality' anahtar kelimeleri ile yayınlanmış ingilizce dilindeki 487 makale tespit edilmiştir. Makalelerin ortalama yaşı 4,95 yıl, belge başına düşen atıf oranı 2014 yılında %37,75 olarak belirlenmiştir. Çalışmalarda yer alan toplam 2160 yazardan 5'i tek yazarlı makalelerde çalışmıştır. Üç Alan Grafiği'ne göre en üretken ülke "Çin", en öne çıkan yazar "Kim Ih.", en sık kullanılan anahtar kelime ise "meat quality" olarak belirlenmiştir.

Bu çalışma, 'broiler', 'feed', 'supplements', 'meat quality' anahtar kelimeleri ile en üretken yazarları, referans alınan makaleleri, kuruluşları, ülkeleri ve akademik alanları belirlemeye yönelik yapılan bibliyometrik çalışmalar arasında yer almaktadır. Çalışmada Scopus veri tabanında indekslenen makaleler incelenmiştir. Makalelerin çoğunun açık erişim olması nedeniyle bu alanda katkıda bulunan yazar sayısı hızla artmakta ve çalışmaları geniş bir şekilde yayımlanmaktadır. Önceki araştırmalara göre, bu alanda en fazla akademik çalışma üreten ülkeler sırasıyla Çin, Mısır ve Güney Kore olup, en çok atıf alan ülkeler ise sırasıyla Çin, Kore ve Amerika Birleşik Devletleri olmuştur.

En üretken dergiler sırasıyla Poultry Science, Brıtısh Poultry Scıence Tropical Animal Health And Productıon olmuştur. Çalışmamızda, konu ile ilgili en çok çalışmaya sahip olan ya da yazarlarının bağlı olduğu kurumun "'Nanjıng Agrıcultural University' olduğu belirlenmiştir. En çok yayın yapan yazar ise 602 makale ile yine "Kim Ih." olarak kaydedilmiştir. En üretken belge, Jiang vd.,2007 yılında Poultry Science dergisinde yayınlanan 'Effects of soybean isoflavone on growth performance, meat quality, and antioxidation in male broilers' makalesi 195 atıf alarak listeye girmiştir.

Anahtar kelime analizi sonucunda, eleman sayısına göre en büyük küme "Meat" olarak adlandırılmıştır. Buna göre en önemli üç kelime 'Meat quality, broiler, growth performance' olmuştur.

Bu çalışmada bilimsel haritalar kullanılarak, 'broiler', 'feed', 'supplements', 'meat quality' alanındaki ilgili araştırmalarda ana eğilimler ve bulgular genel bir bakış açısıyla sunulmuş, yazarların çalışmalarını etkileyen temel temalar, konular ve entelektüel yapılar tanımlanmıştır. Faktör yüklerine göre kırmızı kümede; blood, veterinary medicine, gallus gallus kelimeleri toplanmıştır. Mavi kümede ise body weight, diet supplementation, animal tissue, food intake kelimeleri yer almıştır.

Anahtar kelimelerinin zaman çizelgesi dikkate alındığında, bilimsel araştırmalarda öne çıkan kavramlar; feed additive, chicken meat ve feed kelimelerinin daha çok ön plana çıktığı görülmüştür. Halen literatürde aktif olarak gut microbiata, broiler meat, carcass trait, lipid metobolism, essantial oils kelimeleri yazarlar tarafından çalışılmakta olduğu görülmüştür.

Sonuç

Bu çalışmada, bilimsel başarılar, 'broiler', 'feed', 'supplements', 'meat quality' anahtar kelimeleri ile Scopus veri tabanından elde edilen veriler kullanılarak analiz edilmiş ve değerlendirilmiştir. En iyi araştırmacılar seçilmiş, bölgesel dağılımlar ve yayınlar haritalandırılmıştır. Hem üretilen makale sayısı hem de atıf açısından Çin, en üretken ülke olarak belirlenmiştir. 'Broiler', 'feed', 'supplements', 'meat quality' anahtar kelimeleri ile ilgili makalelerin bibliyometrik değerlendirmesinde, en çok yayın yapan yazar "Kim Ih.", en çok yayınlanan dergi " Poultry Science ", Poultry Science dergisinde yayınlanan 'Effects of soybean isoflavone on growth performance, meat quality, and antioxidation in male broilers' makalesi 195 atıf alarak ilk sırada yer almıştır. Yazarların en önemli anahtar kelimeleri arasında "meat", "diet" ve "male" yer almaktadır. 'Broiler', 'feed', 'supplements', 'meat quality' anahtar kelimeleri ile yapılan araştırmaların kapsamlı bir şekilde özetlenmesiyle, yine bu alanda yeni çalışma alanlarının ve bakış açılarının geliştirilmesine olanak sağlanacağı öngörülmektedir.

Gelecekteki çalışmalar için yönetsel çıkarımlar şu şekilde ifade edilmiştir:

Bu araştırma, mevcut literatürdeki en etkili kaynakları, yazarları, ilişkileri, ülkeleri ve çalışmaları belirleyerek 'broiler', 'feed', 'supplements', 'meat quality' anahtar kelimeleri ile ilgili kritik bilgilerine katkı sağlamaktadır. Uygulayıcılar ve araştırmacılar, hangi makalelerin atıf alacağına, hangi çalışmaların vurgulanacağına ve 'broiler', 'feed', 'supplements', 'meat quality' anahtar kelimeleri ile en büyük etkiye sahip çalışmaların hangileri olduğuna bu bilgiler ışığında karar verebilir.

Bu bibliyometrik çalışma, 'broiler', 'feed', 'supplements', 'meat quality' anahtar kelimeleri ile ilgili önceki ve mevcut araştırmaları ile gelecekteki potansiyel araştırma fırsatlarına kapsamlı bir genel bakış sunmaktadır. Bu anahtar kelimelerin incelenmesi alanında yapılan çalışmaların kapsamlı bir şekilde anlaşılması, akademisyenler için bir referans niteliği taşımaktadır.

Atıflar ve ortak atıflar, araştırmacıların entelektüel yapısını oluşturan birçok araştırma akımını veya disiplini belirlemek için kullanılabilir. Bu yöntem, temaları tespit etmeye ve bilgi edinmeye yardımcı olmaktadır.

Bu çalışma, 'broiler', 'feed', 'supplements', 'meat quality' anahtar kelimeleri ile ilgili çalışmaları incelemek ve hem teorik hem de pratik uygulamalar açısından ileri düzey araştırma alanlarını belirlemek için önemli bilgiler sağlamaktadır. Bu yönüyle hem akademisyenlere hem de uygulayıcılara rehberlik edebilecek bir kaynak niteliği taşımaktadır.

Scopus veri bankası kullanılarak yapılan bu çalışmada 2004-2014 yıllarını içerdiği için ve biblioshiny ve VOSviewer programları kullanılarak filtrelemeler yapılarak sınırlandırılmalar yapılmıştır. Her ne kadar bu analiz Scopus veri tabanına odaklanmış olsa da Web of Science, VOSviewer, R, RStudio gibi diğer veri tabanları da alternatifler arasında yer almaktadır.

Ayrıca, daha ayrıntılı veri kapsamı içeren bir haritalama aracı geliştirilmesi de bir seçenek olarak değerlendirilebilir. Gelecek çalışmalarda, halen literatürde aktif olarak gut microbiata, broiler meat, carcass trait, lipid metobolism, essantial oils kullanılan anahtar kelimeleri üstüne yapılacak olan çalışmalarla literatüre yeni bilgiler katılacağı ön görülmektedir.

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ID: 308

Recent Advances on the Effect of Cold Plasma Treatment on Carotenoids

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Abstract

Cold plasma (CP) technology is gaining recognition as a promising approach in the food industry for preserving the stability and bioactivity of carotenoids. These pigments, abundant in plants and microorganisms, are essential for human health due to their potent antioxidant properties but cannot be synthesized by the human body. CP treatment produces reactive gases by generating plasma at low temperatures, which can inactivate microorganisms and modify enzymatic activity in food systems. The effects of CP on carotenoids are influenced by key parameters such as voltage, treatment duration, type of gas used, and the specific food matrix. CP has the potential to enhance carotenoid content by facilitating their release from cellular structures. However, it may also trigger oxidative reactions that degrade carotenoids under certain conditions. For example, CP treatment has been shown to improve the brightness and redness of carrot juice but reduce its carotenoid content. Conversely, in fruits such as mango, CP can enhance the preservation of carotenoid content during storage. Similarly, in tomatoes, CP treatment has been reported to either increase or decrease lycopene content, depending on the processing conditions. The advantages of CP include its ability to extend the shelf life of carotenoids, its energy efficiency, and its low environmental footprint. Despite these benefits, challenges persist in scaling up CP technology for industrial applications and optimizing its processing parameters. Future research should focus on elucidating the effects of CP on carotenoid stability across diverse food matrices and unlocking the full potential of this innovative technology in the food industry.

Key Words:

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Extraction of Anthocyanins from Food Waste Using Ultrasound- and Microwave-Assisted Methods

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Abstract

Anthocyanins are natural plant pigments responsible for the vibrant red to blue-purple colors in various foods and beverages. They are found abundantly in fruits such as blackberries, blueberries, and strawberries, as well as vegetables like red cabbage and eggplant. Beyond their role as natural colorants, anthocyanins are valued for their significant health benefits. This study explores the definition, sources, biological activities, and applications of anthocyanins in the food industry, with a specific focus on two innovative extraction techniques: ultrasound-assisted extraction (US) and microwave-assisted extraction (MW). US and MW represent advanced, eco-friendly alternatives to conventional extraction methods, offering enhanced speed and efficiency. MW utilizes microwave energy to rapidly heat solvents and plant material, enabling swift extraction, reduced solvent usage, and energy efficiency. However, the technique presents challenges, such as thermal degradation of heat-sensitive compounds and limited compatibility with non-polar solvents. US employs ultrasonic waves to create cavitation, facilitating high extraction yields within shorter timeframes. Several studies highlight the superior performance of US and MW in extracting anthocyanins from food waste. These methods deliver higher yields, reduced extraction times, and lower solvent consumption compared to traditional techniques. By enabling the recovery of valuable bioactive compounds from food waste, these approaches promote sustainable food production systems. Nevertheless, certain limitations persist, including the co-extraction of unwanted compounds, the potential formation of toxic by-products, and the heat sensitivity of anthocyanins. Additionally, scaling up laboratory findings to industrial applications remains a challenge. Overall, US and MW hold immense promise as sustainable and efficient extraction techniques for the food industry. Addressing their limitations through further research and development will pave the way for broader applications and advancements in sustainable food systems.

Key Words:

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High-Throughput Phenotyping of Exotic Tomato Germplasm For Fruit Size, Shape, and Color Diversity

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Abstract

Tomato (*Solanum lycopersicum* L.) is a globally important crop known for its nutritional value and culinary versatility. Consumer preferences for tomatoes are largely influenced by fruit shape, size, and color, making these traits essential targets in breeding programs. This study utilized high-throughput phenotyping to evaluate fruit morphological traits across 81 tomato genotypes using Tomato Analyzer software. The software quantified 47 parameters, including fruit size, shape indices, blockiness, asymmetry, end shapes, angles, eccentricity, and color, through machine learning and geometrical techniques. Conducted at the University of Punjab, Quaid-e-Azam Campus, Lahore, data were extracted from images of fully mature tomato fruits. The results revealed significant phenotypic diversity among genotypes. The first two principal components explained 75.6% of total variance, with PC1 (50.2%) representing a gradient from small, elongated fruits to large, round fruits, and PC2 (25.4%) capturing variations in fruit end shapes and internal structures. Strong correlations between size parameters and shape indices suggested potential inverse relationship for these traits. This study highlighted the efficiency of high-throughput phenotyping in characterizing complex fruit traits, offering a significant improvement over traditional method. The identified morphological diversity provides a valuable resource for breeding programs aimed at developing market-specific tomato cultivars. Moreover, this comprehensive dataset lays the foundation for genetic studies on fruit morphology, facilitating advancements in tomato crop improvement.

Key Words: *Tomato phenotyping, High-throughput phenotyping, Principal Component Analysis (PCA), Tomato Analyzer, Breeding program*

ID: 311

Impact of Ultrasonication on Phase Separation and Sensory Attributes of Tahini

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Abstract

Tahini is a widely consumed traditional product due to its high nutritional value. However, sesame oil, which makes up 55-60% of tahini, separates from the solid components during storage, causing phase separation, which is undesirable for consumers. This study investigated the effectiveness of ultrasound technology in preventing phase separation in tahini. Two different batches of Bozkır tahini with Geographical Indication (produced from hulled and unhulled sesame seeds) were subjected to 35 kHz ultrasound for different durations (1-30 minutes). The results of this study suggest that the application of ultrasound has the potential to improve the stability of tahini and maintain its quality.

Key Words: *tahini, tahiniultrasound, ultrasound technology, phase separation*

Ultrasonikasyonun Tahinin Faz Ayrımı ve Duyusal Özellikleri Üzerindeki Etkisi

Özet

Tahin, yüksek besin değeri nedeniyle yaygın olarak tüketilen geleneksel bir üründür. Ancak tahinin %55-60'ını oluşturan susam yağı, depolama sırasında katı bileşenlerden ayrılarak faz ayrımına neden olur ve bu da tüketiciler için istenmeyen bir durumdur. Bu çalışmada tahinde faz ayrılmasını önlemede ultrason teknolojisinin etkinliği araştırılmıştır. Coğrafi İşaretli Bozkır tahininin iki farklı partisi (kabuklu ve kabuksuz susamdan üretilen) farklı sürelerde (1-30 dakika) 35 kHz ultrasona tabi tutulmuştur. Bu çalışmanın sonuçları, ultrason uygulamasının tahinin stabilitesini artırma ve kalitesini koruma potansiyeline sahip olduğunu göstermektedir.

Anahtar kelimeler: *tahin, tahinultrason, ultrason teknolojisi, faz ayrıştırma*

ID: 313

Effects of Different Drying Methods and Temperatures on the Bioactive Compounds in Purple Carrot Extracts

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Abstract

This study investigated the effects of different drying methods (vacuum, ultrasound-assisted vacuum, and hot air) and temperatures (50, 60, and 70 °C) on the changes in bioactive compounds of purple carrot extracts. The amounts of gallic acid, caffeic acid, hyperoside, quercetin, myricetin, and rutin were evaluated using HPLC analysis. Drying methods, including vacuum (V50, V60, V70), ultrasound-assisted vacuum (USV50, USV60, USV70), and hot air (E50, E60, E70), significantly influenced the phenolic compound content. The results showed that caffeic acid and rutin levels were particularly higher in vacuum and ultrasound-assisted drying methods. The lowest rutin content was observed in fresh carrots (3.76 µg/mL), whereas significant increases were found in USV70 (20.54 µg/mL) and V70 (16.80 µg/mL) samples. Caffeic acid content reached the highest levels in V50 (9.62 µg/mL) and USV50 (10.42 µg/mL) methods. Although compounds like hyperoside and quercetin were present in lower amounts, their levels varied depending on the drying temperatures. These findings highlight the significant impact of drying methods and temperatures on preserving and enhancing bioactive compound levels. This provides an opportunity to develop targeted production strategies for functional food applications using processed products such as purple carrots.

Key Words: *Bioactive compounds, Phenolic profiles, Polyphenols, HPLC, Purple Carrots*

ID: 314

Garlic and Ginger Pastes as natural Antioxidant in Spent Hen Meat Nugget

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Abstract

Economic value of spent hen can be improved through value addition. However, spent hen contain high fat and coupled with the fact that processed chicken meat is more susceptible to oxidative deterioration make spent hen meat products prone to oxidative degradation. Five spent hen chicken nugget emulsions were formulated (T1 ascorbic); T2 0.5% Garlic, T3 1.0% Ginger, T4 0.5% Ginger, T5 1.0%Ginger. The mixtures from each formulation were filled into boxes (20×10 cm) (approximately 40±1 g each), deep fried in Grand Soya oil® for 10 minutes at 190±2oC (frying temperature). The fried nuggets were allowed to cooled down to room temperature and a portion from each nugget was packaged in air tight zip loc bags and stored in a refrigerator (4oC). Frying yield (%), phenol content (GAEmg/g, flavonoid ((mg QE/g), cholesterol (%) and Thiobarbituric reactive substances (TBARS) mg MDA/kg). (Data generated were analysed using ANOVA@Pα0.05. Frying yield 92.29 (0.5% ginger) is similar to 88.62 (0.5% garlic) and significantly higher than 82.29 (ascorbic) and 85.72 (1.5% garlic) but significantly lower than 97.87 (1.5% ginger). Nugget with 1.5% ginger had 24.92 phenol content which is significantly lower (P<0.05) than 20.47 (0.5% ginger), 18.37 (1.5% garlic), 17.63 (0.5% garlic) and 16.06 (ascorbic). Flavonoid (9.34) and cholesterol (72.82) contained in ascorbic nugget is significantly higher than 8.20; 61.84 (0.5 ginger), 8.69; 57.09 (1.5% ginger), 4.71; 68.49 (0.5% garlic) and 6.32; 59.05 (1.5% garlic) for flavonoid and cholesterol respectively. Irrespective of the storage days, ascorbic nuggets had higher TBARS levels than nuggets with ginger and garlic pastes. The reduced cholesterol contents and low levels of TBARS in the spent hen chicken nuggets with ginger and garlic pastes elucidated that both spices can be part of spent hen chicken nuggets formulation.

Key Words: *Nuggets, Oxidative deterioration, Spent hen, Value addition, Scavenging radicals.*

Introduction

The egg industry, at the end of laying cycles produces a significant amount of spent hens as by product (Mahapatra, 1992; Chuaynukool et al., 2007). Spent hen meat is an excellent and cheaper source of animal protein, rich in fat, cholesterol (Sarkar et al., 2020) and similar to broiler meat in term of nutritional quality (Chueachuaychoo et al., 2011). However, despite of these beneficial qualities, spent hens have low economic value (Sarkar et al., 2020). They are most times underutilized and usually used in very low priced minced products (Chuaynukool et al. 2007). This is due to their poor functional characteristics and some sensory properties such as juiciness and tenderness all of which is attributed to the high collagen content they possess (Abe et al., 1996). For instance, spent hen meat still remains tough and fibrous even after cooking with high pressure for a long time (Mendiratta et al. 2012). However, their economic value can be improved through value addition by processing into convenient and shelf stable meat products (Sarkar et al., 2020).

The changing raw meat into to a high quality meat product through processing is usually referred to as value addition of meat. Chicken nugget is an example of food usually preferred by consumers because of its convenience (Sharima-Abdullah et al., 2018) and has been identified as one of the value added meat product that can be used to increase the consumption of poultry meat (Yogesh et al., 2013).

Nugget is a ready to cook and ready-to -eat deep fried meat product usually prepared with chicken meat (Hwuang et al., 2011). Its simple preparation makes it a generally acceptable fried meat products and a popular choice for a quick meal among consumers (Lukman et al., 2009).

Broiler chicken meat is usually used in the production of chicken nuggets because of its high quality characteristics such as high carcasses and better tenderness when compared to spent hen meat (Bhosale et al. 2011). However, throughout the world, broiler chicken meat is of economic importance and also have a good demand for direct meat consumption (Sabikun et al. 2019). It is therefore of utmost importance to find a way of converting the less palatable and tough meat of spent hen into attractive, convenient and more acceptable meat product using appropriate technology. The high fat content of spent hen together with the susceptibility of processed chicken meat to oxidative degradation (Xiao et al., 2011) make spent hen meat products prone to oxidative deterioration. Lipid oxidation in deep fried food has been reported as one of the important criteria that determine the quality and safety of the final product (Izaki et al., 1984). However, this can be reduced or inhibit with the inclusion of

antioxidants in the product during preparation. Antioxidant is one of the strategies and also an effective means used in controlling and reducing the oxidation in meat and meat products (Penchalaraju et al., 2017) as they are the first line of defence against free radicals (Ayoade et al., 2022). This implies that using spent hen meat in the formulation of nuggets will require the incorporation of antioxidant. Natural antioxidants are usually in the form of phenolic compounds such as flavonoids, phenolic acids, tocopherols commonly found in plants (Ali et al., 2008).

Phenolic compounds are group of plant secondary metabolites extensively found across diverse plant, including vegetables, fruits, cereals, legumes, spices and herbs (Balasundram et al., 2006; Zhang et al., 2022). Apart from their use as aroma additives in food many herbs and spices, are excellent sources of phenolic compounds with good antioxidant potentials. Examples of common and readily available spices with good antioxidant properties include garlic and ginger. They are common food spices that are used either singly or in combined form in the diet (Otunola and Afolayan, 2013).

Garlic (*Allium sativum* L.) is culinary spice rich in polyphenolic compounds (Awan et al., 2017; dos Santos et al., 2022) and other bioactive compounds such as flavonoids and organosulfur. These compounds are responsible for its biological activities (Shang et al., 2019; Tavares et al., 2021) such as antioxidant, anti-inflammatory, antimicrobial and immunomodulatory properties (Melguizo-Rodríguez et al., 2022). Fresh garlic bulb contains 65% water, 28% carbohydrates, 2.3% organosulfur compounds, 2% protein, 1.2% free amino acids and 1.5% fiber (Lidiková et al., 2022; Melguizo-Rodríguez et al., 2022).

Ginger (*Zingiber officinale* Roscoe) is usually use in food as a spice (Ali et al., 2008) or seasoning (An et al., 2016). It is composed of phenolic (gingerols, shogaols, and paradols), terpene, polysaccharides, lipids, organic acids and raw fibers (Mao et al., 2019). Fresh ginger contains 85% - 95% water (Prisacaru et al., 2023), 11.97 mg GAE/g total phenolic dry weight (An et al., 2016). This study therefore aimed at investigating the antioxidant potential of garlic and ginger pastes at different inclusion levels in the formulation of spent hen chicken nuggets

Material and methods

Food grade ascorbic acid was purchased from a standard and reputable food stall market. Fresh garlic bulbs were purchased from Bodija a local market within University of Ibadan environment. The garlic (*Allium cepa*) bulb dry skin was removed and the cloves peeled and finely crushed using a kitchen grater. For ginger (*Zingiber officinale* Roscoe), the peels were removed and the fingers cut into slices for easy grinding in the kitchen blender. After grinding, each paste was packed separately in different container until further use.

Sample preparation (raw and cooked nuggets)

Spent hen was obtained from a reputable farm in Ibadan. This was slaughtered, defeathered and cut into primal cuts. Meat was excised from all part of the chicken. All dirts and subcutaneous fat were manually trimmed off and the chicken meat cut into smaller chunks and minced (5mm plate) using a commercial meat grinder. The grounded meat was refrigerated at -4°C until further use. Five spent hen chicken nugget emulsions were formulated (Table 1), each emulsion was thoroughly mixed in an electric mixer for 5minutes to obtain a homogenous mix. The batter from each formulation was filled into boxes (20×20 cm) (raw nuggets) (individual nugget piece weighed 50±1 g/ piece). These were deep fried in Grand Soya oil® at 190±2ºC for 10 minutes with intermittent turning to an inner temperature of 75 °C (using a probe thermometer). The deep fried nuggets were arranged in a tray and placed on a rack and allowed (30 minutes) to cool down to room temperature. The fried nuggets were packaged and stored under refrigeration (4ºC) temperature for further study. The experiment was replicated three times.

Table 1. Ingredient formulation composition of nugget

Ingredients (%)	Ginger			Garlic	
	Ascorbic	0.5%	1.5%	0.5%	1.5%
Chicken meat	70.0	70.0	70.0	70.0	70.0
Ginger paste	0	0.5	1.5	0	0
Garlic paste	0	0	0	0.5	1.5
Ascorbic acid	1.5	0	0	0	0
Refined salt	1.5	1.5	1.5	1.5	1.5
Ice water	5.0	5.0	5.0	5.0	5.0
Pepper	2.0	2.0	2.0	2.0	2.0
0nion paste	2.0	2.0	2.0	2.0	2.0
Skim milk	9.0	10.0	9.0	10.0	9.0
Flour	9.0	9.0	9.0	9.0	9.0
Total	100.0	100.0	100.0	100.0	100.0

Design of the experimental

The study was a completely randomized design. Five different batches nugget were produced: ascorbic, 0.5% garlic, 1.5% garlic, 0.5% ginger and 1.5% and each batch was replicated three times

Parameters measured

pH

Samples (approximately 10g) of each nugget were weighed into a flask followed by addition of 50 mL of distilled water (Nopianti et al., 2012). The samples were then homogenised using an homogeniser (Model Stomacher® 400 Circulator). The pH of homogenized nuggets were measured using pH meter (Model Aqua Lab).

Frying Yield Percentage

Frying yield (%) was calculated, as follows (Naveena et al., 2006):

$$Frying\ yield\ (\%) = \frac{weight\ of\ freshly\ cooked\ spent\ hen\ chicken\ nugget}{weight\ of\ raw\ spent\ hen\ chicken\ nugget} X\ 100$$

Determination of cholesterol content of deep fried nugget

The spectrophotometric procedure was used in determining the cholesterol content of the nuggets as described by Egbert et al. (1991) with slight modifications. Five grams of each of the nugget sample was homogenized and lipid was extracted using the petroleum. The lipid residue was saponified by heating with 8ml of 15% potassium hydroxide in 90% ethanol and 2ml of 3% propyl gallate in water bath at 88°C for 10 minutes and the solvent is later evaporated in a water bath at 50°C. The solution was cool down, and 10ml of petroleum ether added and vortexed for 30 second. After separation, 2mls of the ether layer was pipetted into a clean test tube and evaporated in a water bath in a water bath at 50°C. After evaporation, 3ml of acetic acid saturated with ferrous sulfate and 1ml of concentrated sulphuric acid were added to develop the chromophore for colorimetric analysis of cholesterol. The absorbence was measured with a UV-VIS spectrophotometer at 490mm against a t blank and calculated as;

$$cholesterol\ (mg/g) = \frac{absorbance\ of\ sample\ x\ gradient\ factor\ x\ dilution\ factor}{weight\ of\ the\ sample\ taken}$$

Determination of total phenol and flavonoid contents

These were carried out on the raw garlic and ginger pastes and on the five different cooked Spent Hen Chicken Nuggets (SHCN). The phenol contents were determined using the procedure of Singleton *et al* (1999) through Follin-Ciocalteu reagent and expressed as Garlic Acid Equivalents (GAE). Each sample (200mg) was mixed with 10 ml acetone and extraction with ultrasonic extraction for 20 min (2×10 min, 5 min rest in between) carried out at room temperature. The extract was centrifuged for 10 min at 3000 rpm. One milliliter (1ml) of supernatant was mixed with 0.5 ml Folin-Ciocalteu 1 N and 2.5 ml sodium carbonate, vortexed, and then held for 40 min at room temperature. The absorbance was measured at 725 nm. A standard curve was plotted using different gallic acid concentrations, and the amount of total phenol was calculated as Gallic Acid Equivalents (GAE) in mg/g. The absorbance of both the samples and the standard concentrations were read on a Digital Spectrophotometer at a wavelength of 510 nm. The percentage of phenol is calculated using the formula:

$$phenol\ GAE(mg/g) = \frac{absorvence\ of\ sample\ x\ gradient\ factor\ x\ dilution\ factor}{weight\ of\ sample\ x\ 10{,}000}$$

The total flavonoids were determined spectrophotometrically following the procedure of Zhishen et al. (1999). Total flavonoids of each samples were determined by weighing 5g each of grounded samples into a 100ml beaker and 80ml of 95% ethanol was added and stirred with a glass rod to prevent lumping. The mixture was filtered into a 100ml volumetric flask (through a Whatman No.1. filter paper) and made up to mark with ethanol. One (1) ml of the extract was pipetted into 50ml volumetric flask and four drops of concentrated hydrochloric acid was added after which 0.5g of magnesium turnings was added to develop a magenta red coloration. Standard flavonoid solution of range 0-5ppm were prepared from 100ppm stock solution and treated in a similar way with the hydrochloric and magnesium turnings like sample. The absorbance of magenta red coloration of sample and standard solutions were read on a digital Jenway V6300 Spectrophotometer at a wavelength of 520nm. The percentage flavonoid was calculated using the formula;

$$flavonoids(QE) = \frac{Absorvence\ of\ sample\ x\ gradient\ factor\ x\ dilution\ factor}{weight\ of\ sample}\ x\ 10000$$

Determination of DPPH Radical scavenging activity of ginger, garlic and chicken nugget

Free radical scavenging activities of the garlic, ginger and nuggets were determined using a stable 2, 2-diphenyl-1-picrylhydrazyl radical (DPPH) procedure described by Brand-William *et al*. (1995) and Puntel *et al*. (2005).

Assessment of Lipid oxidation in spent hen meat nugget

The extent of lipid oxidation was assessed using the level of thiobarbituric acid reactive substances in the nuggets at 0, 7 and 14 days. The procedure adopted was described by Radha Krishnan *et al*. (2014) with slight modification and each assessment was carried out in triplicates for each sample The amount of TBARS in the nuggets were expressed as milligrams of malonaldehyde per kilogram of chicken nugget (mg MDA/kg sample).

Statistical analysis

An analysis of variance (ANOVA) was performed on all the data generated and Duncan's multiple range tests at Pα 0.05 was used to determine differences between the treatment means.

Results

Ginger phenol (72.71) and flavonoid (21.06) contents (Table 2) were significantly higher (P<0.05) than 54.91 (phenol) and 18.65 (flavonoid) of garlic.

The DPPH percentage inhibition (Table 3) of ginger 93.68, 88.95, 84.92, 77.67, 71.42 at 5000, 2500, 1250, 625 and 312.5 µg/L were higher (P<0.05) than 90.46, 77.61, 70.39, 63.98 and 49.40 recorded for garlic.

The frying yield (92.20%) of nugget (Table 4) with 0.5% ginger is similar (P>0.05) with 88.62 (0.5% garlic) but significantly higher (P<0.05) than 82.29 (ascorbic) and 85.72 (1.5% garlic) and significantly lower (P<0.05) than 97.87 (1.5% ginger). pH 5.87(0.5% ginger) is similar with 5.43 (1.5% ginger) and 5.63 (0.5% garlic) but significantly higher than 5.33 (1.5% garlic) and lower than6.57 (ascorbic). Phenol (24.92) contained in 1.5% nugget is significantly higher P<0.05) than 16.06 (ascorbic), 20.47 (0.5%ginger), 17.63 (0.5% garlic) and 18.37 (1.5% garlic). Flavonoids (9.34) and cholesterol (72.82) of ascorbic nugget were higher (P<0.05) than 8.20; 61.84 (0.5% ginger), 8.69;57.09 (1.5% ginger), 4.71; 68.49 (0.5% garlic), 6.32; 59.05 (1.5% garlic) recorded for flavonoids and cholesterol contents respectively.

Displayed on (Table 5) is the radical scavenging potential 88.71, 88.51 and 71.86 of nugget with ascorbic at 5000, 2500 and 1250 µg/L were higher P<0.05) than 77.74; 68.71; 65.18 (0.5% ginger), 81.93;72.55; 68.24 (1.5% ginger), 76.00;66.50;53.31 (0.5% garlic), 79.18;71.81;63.20 (1.5% garlic) at concentration 5000, 2500 and 1250 µg/L respectively. At DPPH concentration of 625 µg/L, the inhibition % of nugget with 0.5% (60.88) and 1.5% (61.11) ginger paste were significantly higher (P<0.05) than 56.84 (ascorbic), 45.56 (0.5% garlic) and 54.17 (1.5% garlic). The inhibition % 47.50 of nugget with 1.5% ginger was significantly higher (P<0.05) than 40.90 (ascorbic), 44.32 (0.5% ginger), 36.60 (0.5% garlic) and 38.27 (1.5% garlic).

Table 2. Phenol and flavonoid contents of garlic and ginger used in this study

Parameters (%)	Ginger	Garlic	SEM	P-Value
Phenol GAE mg/g)	72.71^{a}	54.91^{b}	0.091	<.0001
Flavonoids (mg QE/g)	21.06^{a}	18.65^{b}	0.088	<.0001

$^{a,b:}$ Means of different superscripts on the same row signifies differences (P < 0.05)

Table 3. Percentage inhibition of ginger and garlic paste

% DPPH Inhibition				
Concentration (µg/L)	Ginger	Garlic	SEM	P-Value
5000	93.68^{a}	90.46^{b}	0.047	<.0001
2500	88.95^{a}	77.61^{b}	0.114	<.0001
1250	84.92^{a}	70.30^{b}	0.091	<.0001
625	77.67^{a}	63.98^{b}	0.120	<.0001
312.5	71.42^{a}	49.40^{b}	1.287	<.0001

$^{a,b:}$ Means of different superscripts on the same row signifies significant differences between values (P < 0.05).

Table 4. pH, Phenols, Flavonoids and Cholesterol contents of freshly prepared spent hen nugget incorporated with varying inclusion levels of ginger and garlic paste

Parameters	Ascorbic	Ginger		Garlic			
		0.5	1.5	0.5	1.5	SEM	P-value
Frying yield (%)	82.29^{c}	92.20^{b}	97.87^{a}	88.62^{bc}	85.72^{c}	1.931	<.0001
pH cooked nugget	6.57^{a}	5.87^{b}	5.43^{bc}	5.63^{bc}	5.33^{c}	0.223	0.0002
Phenols (GAE mg/g)	16.06^{e}	20.47^{b}	24.92^{a}	17.63^{d}	18.37^{c}	0.104	<.0001
Flavonoids (mg QE/g)	9.34^{a}	8.20^{c}	8.69^{b}	4.71^{e}	6.32^{d}	0.048	<.0001
Cholesterol (%)	72.82^{a}	61.84^{c}	57.09^{e}	68.49^{b}	59.05^{c}	1.931	<.0001

$^{a,b,c,d,e:}$ Means with different superscripts on the same row are significantly different (P < 0.05)

Table 5. Radical scavenging activity of freshly prepared spent hen chicken nugget with varying inclusion levels of ginger and garlic paste

Concentration(µg/L)	% DPPH Inhibition						
	Ascorbic	Ginger		Garlic			
		0.5	1.5	0.5	1.5	SEM	P-Value
5000.0	88.71[a]	77.74[d]	81.93[b]	76.00[e]	79.18[c]	0.170	<.0001
2500.0	88.51[a]	68.71[d]	72.55[b]	66.50[e]	71.81[c]	0.085	<.0001
1250.0	71.86[a]	65.18[c]	68.24[b]	53.31[e]	63.20[d]	0.302	<.0001
625.0	56.84[b]	60.88[a]	61.11[a]	45.56[d]	54.17[c]	0.142	<.0001
312.5	40.90[c]	44.32[b]	47.50[a]	36.60[e]	38.27[d]	0.135	<.0001

[a,b,c,d,e:] Means of different superscripts on the same row are significantly different (P < 0.05).

Table 6. Thiobabituric Acid Reactive Substances values during storage of spent hen meat nuggets with varying inclusion levels of ginger and garlic pastes

Storage days		Ginger		Garlic			
	Ascorbic	0.5	1.5	0.5	1.5	SEM	P-value
0	0.53[a]	0.20[d]	0.18[e]	0.28[b]	0.22[c]	0.025	<.0001
7	0.55[a]	0.24[d]	0.18[e]	0.39[b]	0.32[c]	0.017	<.0001
14	0.64[a]	0.45[b]	0.25[d]	0.40[b]	0.37[c]	0.012	<.0001

[a,b,c,d,e:] Means of different superscripts on the same row are significantly different (P < 0.05)

The TBARS (Table 6) at days 0 (0.53), 7 (0.55) and 14 (0.64) were significantly higher (P<0.05) than 0.20;0.24;0.45 (0.5% ginger), 0.18; 0.18;0.25 (1.5% ginger), 0.28; 0.39;0.40 (0.5% garlic) and 0.22;0.32;0.37 (1.5% garlic) recorded at 0, 7 and 14days respectively.

Discussion

The phenols and flavonoids results showed that ginger and garlic possess high amount of phenols and flavonoids with ginger containing higher amounts of both compounds. This result further confirm that ginger is one of the plants that is rich in phenolic compounds (Mahmudati et al., 2019).

Di-phenyl picry hydrazil (DPPH) is widely used as a free radical scavenging assay to evaluate the antioxidant activity of compounds (Ayoade et al., 2022). The DPPH assay is an easy, rapid and convenient method of evaluating antioxidants and radical scavengers (Bao et al., 2005). The percentage Hydroxyl (OH) radicals of ginger and garlic in this study although dose dependent were high indicating a high scavenging ability of hydroxyl radicals in both spices. This trend was also reported by Ayoade et al. (2022) who reported a DPPH of 85.358 and 87.694 for ginger and 83.956 and 79.751 for garlic from aqueous and ethanol extracts respectively.

The pH of the spent hen chicken nuggets with garlic and ginger in this study were lower than what was obtained in nugget with ascorbic acid. This low pH might be attributed to the rich bioactive compounds (Khatun et al., 2022) of both garlic and ginger. The pH of nuggets here was lower than 6.01 to 6.11 recorded by Khatun et al. (2022) in chicken nugget formulated with carrot and ginger.

The frying yield showed that as the inclusion of ginger paste increased the nugget yield increased while the reverse is observed in the nugget with garlic paste inclusion. This could be as a result of the higher water percentage (85-95%) contained in ginger (Prisacaru et al., 2023) when compared to 65% (Melguizo-Rodríguez et al., 2022) in garlic. The yield from garlic and ginger pastes nugget of this study was higher than 88.0-89.3% obtained in nugget with added fat and variable salt contents (Yogesh et al., 2013) and 76.5 - 85.6 g obtained in spent hen nuggets with milk fat and potato mash.

Normally, raw poultry meat usually has a cholesterol content of approximately 27- 90 mg/100 g while that of cooked poultry meat falls within the range of 59 to 154 mg/100g (Bragagnolo, 2009). Nugget samples formulated with various levels of ginger or garlic pastes significantly had lower levels of cholesterol than nuggets with food grade ascorbic acid. The cholesterol content of the spent hen nugget tends more to the lower limit of the required/permissible amount of cholesterol in meat products. This implied a healthier meat products as high cholesterol in food has been reported to have a negative effect on human health.

The higher level of phenol content recorded in the spent hen chicken nugget with ginger paste might be due to the ginger having a high phenolic content (Table 2). This same trend was also reported by Zhang et al. (2016) who opined that the high phenolic content in duck nugget with black garlic powder was due to the high phenolic content of the black garlic powder.

The DPPH scavenging activities of both ginger and garlic used in this study depict that they are dose responsive as scavenging activities increased with higher concentration of either compound. This same trend was also noticed with the spent hen nuggets as scavenging activity respond positively to increase concentration of the pastes in the spent hen nugget.

This further elucidated that scavenging radicals can be inhibited in meat and meat product by adding antioxidant compounds (Lishianawati et al., 2021). The result of the DPPH also revealed that ginger had a higher scavenging potential than garlic thus confirming that ginger had a high antioxidant capacity (Widayat et al., 2017). This also agreed with Ahmed et al. (2019) who reported that ginger exhibited higher scavenging activity than garlic and Nuutila et al. (2003) and Capasso (2013) who both reported lower antioxidant activity in garlic.

The high scavenging potential of the ginger was attributed to the high phenolic contents of ginger (Table 2). This is because phenolic compounds are phytochemicals found in plants and spices which account for most of their antioxidant activities (Ayoade et al., 2022). They are also the major primary antioxidant group of compounds or free radical terminators (Lishianawati et al., 2021) thus the high scavenging potential observed in ginger.

The lipid inhibition by ascorbic, garlic and ginger (Table 6) was obvious throughout the storage period (14 days) as all products did not exceed the permissible limits of TBARS value of 0.90 mg MDA/kg for meat and poultry products (Egyptian Organization for Standardization and Quality Control, 2005; El-Sohaimy et al., 2022). However, at the beginning (zero day) of the experimental storage, there was remarkable significant differences in TBARS levels among the different nugget's samples. The pre-treatment of the chicken nugget ingredients with garlic and ginger pastes reduced lipid oxidation drastically when compared with nugget with food grade ascorbic acid. The potency of ginger and garlic in retarding lipid oxidation in SHCN in the present study implied that there is low aldehyde compounds accumulation which further emphasizes the usefulness and importnace of utilizing ginger and garlic paste in processed meat products such as chicken nuggets.

Furthermore, the antioxidant effect of garlic and ginger paste on spent hen nugget at refrigerated storage was more pronounced with nugget with ginger paste having a lower TBARS value. This effect might be probably due to the fact the ginger contains higher content of phenol and flavonoid (Table 2). This is because linear correlation exists between phenolic content and antioxidant activity (Gheldof and Engeseth, 2002) thus high phenol content increases antioxidant activity (Velioglu et al., 1998; Holasova et al. 2002). Furthermore, higher flavonoids also indicate higher scavenging activity because flavonoids also function in scavenging free radicals, inhibition of peroxidants and chelating transition metals (Nickavar et al., 2007). The antioxidative effectiveness of ginger in reducing lipid oxidation was also reported by Baker and Alkas (2020) when ginger and rosemary extracts were compared on their potency in increasing meat quality. However, the TBARS of nugget with ginger and garlic paste inclusion at end of the storage period did not exceed 0.5 mg/kg reported to be the threshold at which rancid flavour can be detected by consumer (Choi et al., 2010). The obtained TBARS in either of the two spices pastes was lower than 0.46 mg MDA/kg reported in nugget with quinoa flour after 18 days of cold storage (El-Sohaimy et al., 2022).

Conclusion

Quality characteristics of fresh and stored spent hen chicken nuggets with ginger and garlic pastes were highly remarkable implying that both spices can be part of spent hen chicken nuggets formulation. This is evident in the reduced cholesterol contents of the freshly prepared deep fried spent hen chicken nuggets. Furthermore, ginger and garlic pastes were highly effective in reducing the rate oxidative deterioration of the nuggets which is exhibited in the low TBARS when compared with ascorbic acid marinated nuggets. This implied that addition of bioactive compounds such as ginger and garlic pastes up to 1.5% inclusion will be an effective functional ingredient for maintaining the quality attributes especially deterioration of lipid during storage of spent hen chicken nugget. The findings of this study elucidated that spent hen can be effectively utilized by processing into better-accepted, convenience ready-to-eat and shelf stable meat products such as chicken nugget.

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ID: 316

Investigation of in vitro Antibacterial Potential of Various Wood Vinegars Against Plant Bacterial Disease Agents

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Abstract

Wood vinegar, also known as pyroligneous acid (PA), is a liquid mixture with organic properties obtained from the condensation of smoke produced by the charring or pyrolysis of wood. The aim of this study was to determine the *in vitro* antibacterial activity of three different PAs obtained from the pyrolysis of apricot kernels (AKPA), hazelnut shells (HSPA), and kermes oak (OPA) against plant pathogenic bacterial species such as *Curtobacterium flaccumfacies* pv. *flaccumfaciens*, *Pectobacterium carotovorum* subsp. *carotovorum*, *Pseudomonas syringae* pv. *phaseolicola* and *Bacillus pumilus*. The antibacterial activity of wood vinegar on the development of disease agents was evaluated by measuring the inhibition zone diameters under in vitro conditions using the disk diffusion technique. According to the mean inhibition zone diameters, the most effective PA was HSPA with a zone diameter of 20.33, followed by AKPA and OPA with zone diameters of 20.13 and 19.33, respectively. The highest antibacterial activity was shown by HSPA against *C. flaccumfacies* pv. *flaccumfaciens* (24.17 mm inhibition zone diameter), followed by AKPA and OPA treatments with 23.33 and 21.17 mm inhibition zone diameters, respectively. According to the mean inhibition zone diameters, the most susceptible bacterial species was shown against *C. flaccumfacies* pv. *flaccumfaciens* with a zone diameter of 22.89, followed by *Pectobacterium carotovorum* subsp. *carotovorum*, *Pseudomonas syringae* pv. *phaseolicola* and *B. pumilus* with zone diameters of 19.89, 18.50 and 18.44, respectively. Among the bacterial disease agents, *C. flaccumfacies* pv. *flaccumfaciens* was found to be the most sensitive to the three PAs used in the study. AKPA and HSPA were the most effective treatments against *C. flaccumfacies* pv. *flaccumfaciens*, while OPA was the most effective against *C. flaccumfacies* pv. *flaccumfaciens* and *P. carotovorum* subsp. *carotovorum*. The results obtained showed that wood vinegar has the potential to be used as a bio-bactericide against important plant bacterial disease agents.

Key Words: *Antibacterial; Wood vinegar; Plant bacterial pathogens; Organic farming*

ID: 317

Assessment of Selected Heavy Metals in Water, Sediment and Muscles of Some Edible Finfishes - Schilbe mystus, Sarotherodon galileus, Mormyrus rume and Clarias anguillaris from Ajiwa Irrigation Dam, Katsina State, Nigeria

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Abstract

The freshwater fishes (*Schilbe mystus, Sarotherodon galileus, Mormyrus rume and Clarias anguillaris*) are the most commercially important finfishes in Nigeria. Investigations were made on the accumulation of five (5) heavy metals: Lead (Pb), Chromium (Cr), Iron (Fe), Cadmium (Cd), and Zinc (Zn) collected from water, sediment and *fish organs* (gills, intestines and flesh) inhabiting the Ajiwa dam. Standard methods analyses revealed low accumulation of metals in the water and flesh of the finfishes for both seasons compared to the sediment. The mean concentration of heavy metals decreased in this sequence: Fe>Zn>Pb>Cr>Cd (wet season) and Fe>Zn>Cr>Cd>Pb (dry season) for all sampled fish organs. Fe had the highest mean concentration (106±2.30mg/l) in all the samples while Cd (0.43±0.02mg/l) and Pb (0.22±0.01) had the least mean concentration for the wet and dry seasons respectively. The bio-water accumulation factors showed that the flesh accumulated all the five metals with Fe (>0.5mg/l) as the highest and Zn (≤0.221mg/l) as the least. The bio-sediment accumulation factors in the flesh were ≤2 mg/kg. The results of heavy metals concentrations obtained from the sampled fish organs and water from the dam were within the limit of FAO/WHO recommendation for human consumption and striving of the finfishes.

Key Words: *Ajiwa dam, bioaccumulation, finfish, Mormyrus rume, seasonal*

Introduction

Decades ago, the ability of the aquatic ecosystem to sustain this important aquatic resource (fishes) has come under threat, as a result of increasing contamination of surface water and sediments in the aquatic medium as it accumulates in aquatic organisms (planktons and invertebrates) and invariably, bioaccumulates in humans, the final consumer of the aquatic resources, which now pose a great concern globally (Malik et al., 2010; Aghoghovwia *et al*., 2016; Hossain *et al*., 2016; Akinjogunla and Lawal-Are, 2020; Akinjogunla *et al*., 2023). Water plays a very significant role in the life of human and aquatic organisms. Water with zero content of toxicant is essential for living a healthy life since polluted water can pose humans health at risk through direct or indirect contact with dangerous chemicals (Akinjogunla *et al*., 2023).

In the recent times, Ajiwa irrigation Dam, Katsina has been subjected to a lot of anthropogenic pollutants capable of impairing the healthy status of the river with the influence of inhabitants and fisherfolks on the dam (Akinjogunla and Shuai'bu, 2022). Aquatic contamination has been increased by industrial revolution, mechanical waste and anthropogenic activities. Significant pollutant discharge into water have resulted to magnanimous hazards to the fresh water ecosystem. Contaminants of aquatic systems with heavy metals is one of the most challenging problems globally now, because of their toxicity, persistency and ability of bioaccumulation (Zeitoun and Mehana, 2014). Metals accumulate in sediment at a considerable amount and finally enters into the food chain through water and plants (Bhuyan and Islam 2017).

Finfishes constitute major sources of animal protein intake of human, (Akinjogunla *et al*., 2021; Akinjogunla and Usman, 2023; Akinjogunla and Shehu, 2024), particularly in developing countries and are consumed or presented in various palatable ways (fresh, cooked, grilled, dried, fried or smoked) depending on individual's taste, preference or socio-economic status (Akinjogunla *et al*., 2017). Fishes are the most important aquatic biota and are susceptible to heavy metals pollution (Akan *et al*. 2012).

Heavy metal toxic waste is considered as a major ecological disaster because of its inability to breakdown to smaller harmless pieces and so, they regenerate to survive in the environment and also in the aquatic organisms (Ayangbenro and Babalola 2017). In aquatic system, the ambient environment (water and sediment) is usually the medium and receiving point of these metal pollutants (Gilbert &Avenant-Oldewage 2014). Pollution appraisal in an environment based on water analyses only is not a comprehensive and precise method of identifying contaminants in aquatic systems (Ismail *et al*. 2016) while metal concentration in sediment is also an indispensable tool in water quality evaluation (Abdel-Khalek *et al.* 2016). The biotic and abiotic properties of the aquatic

environment differ from one habitat or ecosystem (marine, estuarine or freshwater) to another. Human activities (domestic or industrial) that can result in the alteration of the waterbeds, presence or absence of fauna (preys or predators), support or impeding of aquatic growths etc. can lead to degradation of water quality (Verma *et al.*, 2012).

The concentration of metals becomes toxic to both the fish and the final consumer (human and animals) when it exceeds the permissible level (Abdallah et al., 2012; Adaka *et al.*, 2017; Akinjogunla and Lawal-Are, 2020; Okunade *et al*., 2021; Akinjogunla *et al*., 2023). This threshold limit varies not only between different metals but also among different species. Metals become toxic when the metabolic activities of the organism fail to detoxify them (Mansour and Sidky, 2002). Exposure to heavy metals could eventually lead to health hazards or threats connected with the ingestion of contaminated / polluted fish by man. All these sources of pollution affect the physiochemical characteristics of the water, sediment and biological components (Akinjogunla et al., 2023), and thus the quality and quantity of fish stocks (Mantovani, *et al.*, 2005; Singh, *et al*., 2006).

Schilbe mystus, Sarotherodon galileus, Mormyrus rume and Clarias anguillaris are freshwater fishes that are of great commercial importance and in abundance in the study area (Akinjogunla and Shuaibu, 2022). Fish and other aquatic food are capable of concentrating heavy metals in their tissues (Akinjogunla and Lawal-are, 2020; Akinjogunla et al., 2023) and for the fact that they play a vital role in human nutrition, they need to be checked properly to ensure that unnecessary high level of some organic and inorganic pollutant is not being transferred to human through consumption.

To the best of our knowledge, from literature survey, no work has been reported on the assessment of heavy metals in fishes, sediments and water of the Ajiwa Irrigation Dam. Therefore, in this study we accessed the concentration levels of selected heavy metals such as Cadmium (Cd), Lead (Pb), Chromium (Cr), Zinc (Zn) and Iron (Fe) in the four commonly consumed finfishes (*Schilbe mystus, Sarotherodon galileus, Mormyrus rume and Clarias anguillaris)* tissues (gills, intestine, flesh) of the Ajiwa irrigation Dam.

Materials and Method

Sampling Area

Ajiwa Irrigation dam / reservoir (Figure1) is located at Batagarawa Local Government Area of Katsina State (Akinjogunla and Shuai'bu, 2022) with its primary purpose of suppling water but as time goes on, fishing activities was added (Akinjogunla and Usman, 2023).

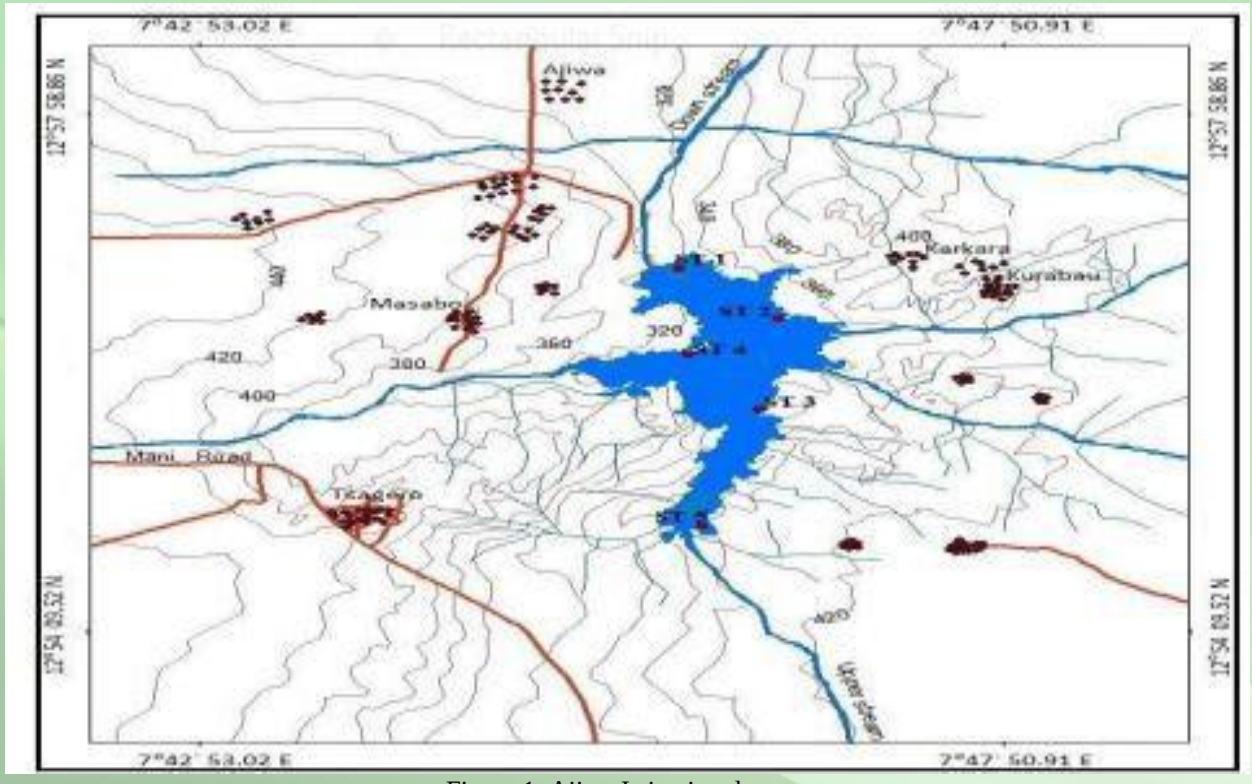


Figure 1. Ajiwa Irrigation dam
Source: Akinjogunla and Shuai'bu, 2022

Sampling stations
Along the river, three (3) sampling stations were selected and named as sampling station A, B, C across the Dam area, with particular reference to areas where there are continuous human interactions and discharge of wastewater.

Water sample collection
Water samples were collected at each sampling station (Station A, B, C) for a period of six (6) months. Water sampling was done by immersing sampling bottles at about 10cm below the water surface. A volume of 500 ml of water sample was collected from each sampling station.

Sediment Sample Collection
Sediment from each study station was collected using hand trowel into pre-cleaned polythene bag for the period of six (6) months between July (which marked the peak of rainy season) to December, 2023 which marked the peak of dry season. All the samples were collected under the same condition. The sediment samples collected were kept in polyethylene bags and preserved under a freezing condition (< -20 °C) before laboratory analysis.

Fish Samples Collection and Identification
Four (4) fish species (*Schilbe mystus, Sarotherodon galileus, Mormyrus rume and Clarias anguillaris*) were collected monthly for a period of six months at the fish landing site of the dam. The fishes were washed using the dam water and preserved in an ice cooler and transported to the Department of Biochemistry laboratory, Gombe State University, Gombe State.

Samples Preparation and Analysis
Water sample
Raw water was subjected to wet digestion. 100ml unfiltered water was measured into a 250ml beaker and 20ml "Analar" nitric acid solution plus 10ml of 50% hydrochloric acid solution was added. The acidified water was evaporated to almost dryness on a hot plate and 5ml of 50% hydrochloric acid was again added and heated for 15 minutes. The beaker was removed and cooled to room temperature before transferring the contents into a 100ml volumetric flask and made up to the mark with distilled water (Wufem *et al*., 2009). The digested water was filtered and analyzed for the levels of heavy metals using AA6800 (Shimadzu Japan). Atomic Absorption Spectrophotometer (AAS).

Fish samples
The fish organs (gills, intestines and flesh) were eviscerated and then transferred into electric oven at 40^0C. They were dried in the oven at this temperature for 24 hours and then pulverized in a clean dry porcelain mortar (Ahmed *et al*., 2010). The pulverized samples were dried further for 1hour at a reduced temperature of 20^0C and put into clean dried bottles. 3.0g of the dried fish samples was weighed into a silica crucible and ashed in a muffle furnace at a temperature of 600^0C for 5 hours (Adeniyi *et al*., 2005). The ashes were cooled to room temperature and sieved to remove particles and then transferred into a 250ml conical flask. Thereafter, 20ml of concentrated HNO_3 was added and diluted to 50ml with deionized water and swirled gently after which the volume was made up to 100ml with deionized water and analyzed for heavy metals as with the water.

Sediment
Sediment Samples were dried, ground and sieved with 200mm mesh screen. For each sample, 5.0g of sediment was measured into 150ml flasks. 50ml of 0.1M HCl was added and the flasks was agitated for 30 mins at 200 rev/min. The mixture was filtered into 50ml flask and made up to the mark with deionized water (Ahmed *et al*., 2010).

Chemical Analysis
Flame atomic absorption spectrophotometry (FAAS) AA6800 (Shimadzu Japan) supplied with ASC-6100 auto sampler and air acetylene atomization gas mixture with elements specific hollow cathode lamp was used for the determination of the targeted heavy metals at Department of Biochemistry laboratory Gombe State University, Gombe State. Analytical grade standards of each target heavy metals were used.

Determination of Bioaccumulation Factors
The bioaccumulation factors of the heavy metals in the organs, water and sediment were determined using the method adopted to gauge the bioaccumulation of trace metals as advocated by the FEPA (2003) in the tissues of commonly consumed fish.

$$BWAF = \frac{Heavy\ metal\ concentration\ in\ organs}{Heavy\ metal\ concentration\ in\ water}$$

$$BSAF = \frac{Heavy\ metal\ concentration\ in\ organs}{Heavy\ metal\ concentration\ in\ sediment}$$

Statistical Analysis

Data generated from this study were analyzed as mean ± standard error using Microsoft Excel 2010. All means recorded were determined considering a level of significance less than 5% ($p < 0.05$) at 95%. It was used to test for significant relationship among heavy metals levels in muscle, water and sediment of the sampling site.

Results

The mean concentration of Cadmium (Cd), Lead (Pb), Chromium (Cr), Zinc (Zn) and Iron (Fe) in the various tissues (gills, intestines and flesh) of common edible fishes (*Schilbe mystus – S. mystus, Sarotherodon galileus – S. galileus, Mormyrus rume – M. rume* and *Clarias anguillaris – C. anguillaris*), sediment and water from three (3) sampling points at the Ajiwa Irrigation Dam in Kastina State during the wet and dry seasons is reported in Table 1.

Table 1. The concentration (Mean ± SD, in mg/kg) of metals in tissues of fish samples obtained from Ajiwa irrigation Dam, Katsina during both wet and dry seasons.

	S. mystus			*C. anguillaris*		
M	Gills	Intestine	Flesh	Gills	Intestine	Flesh
Wet Season						
Cd	1.16 ± 0.04	1.45±0.05	1.40± 0.01	0.43± 0.02	0.48±0.01	0.44±0.01
Pb	2.11±0.02	1.21±0.15	1.28±0.20	1.57± 0.01	1.58±0.01	2.00±0.01
Cr	1.47± 0.02	1.48±0.02	1.35± 0.03	0.51±0.03	0.51±0.02	0.49± 0.01
Zn	3.20± 0.14	3.14±0.01	2.23± 0.15	8.85±0.05	8.55±0.04	8.30±0.03
Fe	106± 2.30	98± 2.23	105 ± 2.33	33.0 ±0.05	13.68±0.40	10.20± 0.10
Dry Season						
Cd	0.47 ± 0.02	0.43±0.02	0.34± 0.01	0.60± 0.02	0.60±0.02	0.31±0.01
Pb	0.44±0.02	0.34±0.02	0.22±0.01	0.53± 0.03	0.52±0.02	0.28±0.01
Cr	0.81± 0.02	1.00±0.02	0.98± 0.01	0.79±0.02	0.79±0.02	0.40± 0.01
Zn	36.6± 0.14	30.0± 0.06	36.6± 0.15	35.00±0.02	35.01±0.01	34.00±0.03
Fe	60.6± 0.21	60.5± 0.22	63.6 ± 0.21	53.00 ±0.05	53.00±0.05	52.01± 0.04
	M. rume			*S. galileus*		
M	Gills	Intestine	Flesh	Gills	Intestine	Flesh
Wet Season						
Cd	1.28±0.02	1.10±0.05	1.10 ±0.01	1.02±0.03	1.24±0.02	1.18±0.01
Pb	2.62±0.17	2.55±0.14	2.18±0.16	2.47±0.01	2.38±0.01	2.43±0.02
Cr	1.29±0.11	1.20±0.12	1.23±0.01	1.33±0.02	1.28± 0.02	1.35± 0.01
Zn	2.83±0.21	3.44±0.21	2.33±0.19	2.98±0.02	1.98±0.02	2.60± 0.01
Fe	100±1.52	101±1.82	99±1.72	94.7± 1.53	16.14±0.23	19.12±0.19
Dry Season						
Cd	0.39±0.02	0.49±0.02	0.48 ±0.01	0.60±0.01	0.31±0.02	0.30±0.01
Pb	0.25±0.03	0.46±0.02	0.45±0.03	0.40±0.01	0.22±0.01	0.26±0.02
Cr	0.76±0.03	0.76±0.02	0.77±0.03	1.76±0.02	0.75± 0.02	1.76± 0.01
Zn	37.6±0.23	37.6±0.23	38.00±0.21	35.2±0.02	34.22±0.02	34.20± 0.01
Fe	55.5±3.07	55.44±3.07	54.50± 3.03	54.1± 0.15	54.10±0.16	53.11±0.14

Keys: M: Metals (Mg/kg); Cadmium (Cd); Lead (Pb); Chromium (Cr); Zinc (Zn); Iron (Fe); *Schilbe mystus – S. mystus; Sarotherodon galileus – S. galileus; Mormyrus rume – M. rume* and *Clarias anguillaris – C. anguillaris*

The mean concentration of heavy metals in the fish tissues decreased in the following sequence: Fe>Zn>Pb>Cr>Cd in wet season and Fe>Zn>Cr>Cd>Pb in dry season for all sampled fish organs. There were no significant differences ($p>0.05$) of these metals observed between the sampled fish tissues, water and sediment and seasons. Fe recorded the highest mean values in both seasons (106±2.30mg/kg for wet season and 63.6±0.21mg/kg for dry season). Cd concentration has the lowest value (0.43±0.02mg/kg) in the gills of *C. anguillaris* in wet season while Pb had the lowest value (0.22±0.01mg/kg) in the flesh of *S. mystus* and intestines of *C. anguillaris* in the dry season.

In this study, the gills and flesh of *S. mystus* were recorded to contain the highest levels of Fe for the wet and dry seasons respectively while its intestines were recorded to have the highest value of Cd during the wet season only. The flesh of C. *anguillaris* recorded the lowest value of Fe for both seasons while its gills were recorded to have the lowest value of Cd during the wet season. During the dry season, the intestines of *M. rume* had the highest value of Pb while the intestines of *S. galileus* and *S. mystus* had the lowest levels of Pb.

Table 2. The concentration (Mean ± SD, in mg/l metals in water samples for both Wet and dry seasons obtained from Ajiwa irrigation Dam, Katsina.

Heavy Metals						
Season	Parameters	Cd	Pb	Cr	Zn	Fe
Wet	Water (mg/l)	0.44± 0.02	0.27 ± 0.02	0.07 ± 0.03	69.00±0.36	2.29±0.02
	Sediment (mg/kg)	0.63± 0.15	0.30 ± 0.02	0.60 ± 0.05	69.9±0.31	2.35±0.03
Dry	Water (mg/l)	1.21± 0.03	2.60 ± 0.02	1.56± 0.05	72.10±0.31	90.66±0.03
	Sediment (mg/kg)	1.35± 0.04	2.77 ± 0.03	1.44 ± 0.03	72.2±0.26	106.0±2.57
WHO (2011) tolerance limit	Water (ppm)	0.001– 0.005	0.1	0. 1	0.10	5.00
	Sediment (ppm)	0.l	5.00	0.03 - 0.3		5.00

Keys: Cadmium (Cd); Lead (Pb); Chromium (Cr); Zinc (Zn); Iron (Fe)

Table 2 below shows the mean concentration of these heavy metals (Cd, Pb, Cr, Zn and Fe) in the sampled water and sediments from the Ajiwa Irrigation dam. The highest metal accumulated was Fe (90.66±0.03mg/l and 106.0±2.57mg/kg) for both water and sediment samples respectively during the dry season while the lowest metal accumulated was Cr (0.07 ± 0.03mg/l and 0.60 ± 0.05 mg/kg) for water and sediment samples respectively for the wet season

The values recorded for Cd exceeded the tolerance limits for both sediment and water samples for both wet and dry seasons while values of Pb obtained in this study were within range for the sediment samples for both seasons but the values obtained for the water samples exceeded the WHO limits.

The values recorded for Cr during this study exceeded the tolerance limits for sediment samples for both seasons and water samples for the dry season only. Zn values exceeded the tolerance limits for both water and sediment samples for both the wet and dry seasons while Fe values recorded during the wet seasons for both water and sediment samples were within the limits but values obtained for both water and sediment samples for the dry season exceeded the acceptable tolerance values.

In Table 3, the bioaccumulation factor of fish tissues to water (BWAF) is presented. Cd values ranged between 0.503 in the gills of *C. anguillaris* to 1.661 in the flesh of *S. mystus* while Pb values were between 0.731 in the gills and intestines of *C. anguillaris* to 1.348 in the gills of *S. galileus*. Cr values ranged between 0.552 (in the gills and intestines of *C. anguillaris*) and 1.932 (in the intestines of *S. mystus*). Lowest to the highest values for Zn ranged from 0.221 in the intestines of *S. mystus* to 0.310 in the gills of *C. anguillaris*. The highest and lowest values of Fe (0.775 and1.813) were recorded for intestines of *S. galileus* and the flesh of *S. mystus* respectively. The least recorded values of Fe, Cr and Cd were found in sampled organs of *C. anguillaris* while least values for Zn and Pb were alternated between sampled organs of *S. galileus* and *S. mystus* respectively.

Table 4 shows the bioaccumulation factor between the fish tissues and sediments (BSAF) collected from the Ajiwa Irrigation dam, Katsina. Cd values recorded ranged across the sampled fish organs (gills, intestines and flesh) of the four selected fish samples from 0.410 (in the gills of *C. anguillaris*) to 1.380 (in the flesh of *S. mystus*). Pb values ranged between 0.537 in the intestines of *S. mystus* to 1.800 in the gills of *M. rume*. The values of Cr recorded was between 0.593 (flesh of *C. anguillaris*) and 2.093 (intestines of *S. mystus*) while the values for Zn recorded ranged from 0.219 in the intestines of *S. mystus* to 0.494 in the intestines of *S. galileus*.

The recorded values for Fe were between 0.523 from the intestines of *C. anguillaris* to 1.537 from the gills of *S. mystus*. Sampled tissues of *C. anguillaris* accumulated the least values of all the heavy metals examined while the highest values accumulated rotates between *S. mystus*, *M. rume* and *S. galileus*.

Table 3. Mean concentration of the bioaccumulation factor of fish tissues to Water (BWAF).

SAMPLE	TISSUES	Cd	Pb	Cr	Zn	Fe
S. mystus	Gill	0.987	0.993	1.398	0.275	1.792
	Intestine	1.078	0.574	1.932	0.221	1.705
	Flesh	1.661	0.592	1.429	0.275	1.813
M. rume	Gill	1.012	1.069	1.196	0.284	1.672
	Intestine	1.151	1.048	1.202	0.283	1.673
	Flesh	0.896	0.986	1.220	0.285	1.651
S. galileus	Gill	1.152	1.348	1.282	0.263	1.601
	Intestine	1.545	1.324	1.245	0.263	0.755
	Flesh	0.896	1.344	1.294	0.256	0.777
C. anguillaris	Gill	0.503	0.731	0.552	0.310	0.925
	Intestine	0.533	0.731	0.552	0.308	0.609
	Flesh	0.515	0.874	0.546	0.299	0.669

Keys: Cadmium (Cd); Lead (Pb); Chromium (Cr); Zinc (Zn); Iron (Fe); *Schilbe mystus – S. mystus; Sarotherodon galileus – S. galileus; Mormyrus rume – M. rume* and *Clarias anguillaris – C. anguillaris*

Table 4. Mean concentration of the bioaccumulation factor of fish tissues to Sediments.

SAMPLE	TISSUES	Cd	Pb	Cr	Zn	Fe
S. mystus	Gill	0.823	0.928	1.520	0.273	1.537
	Intestine	0.898	0.537	2.093	0.219	1.462
	Flesh	1.38	0.553	1.553	0.273	1.555
M. rume	Gill	0.843	1.800	1.300	0.282	1.435
	Intestine	0.959	0.980	1.306	0.281	1.443
	Flesh	0.747	0.921	1.333	0.283	1.416
S. galileus	Gill	0.959	1.260	1.393	0.261	1.373
	Intestine	1.287	1.237	1.353	0.494	0.648
	Flesh	0.747	1.253	1.406	0.254	0.667
C. anguillaris	Gill	0.419	0.684	0.600	0.308	0.790
	Intestine	0.444	0.686	0.600	0.306	0.523
	Flesh	0.429	0.817	0.593	0.297	0.574

Keys: Cadmium (Cd); Lead (Pb); Chromium (Cr); Zinc (Zn); Iron (Fe); *Schilbe mystus – S. mystus; Sarotherodon galileus – S. galileus; Mormyrus rume – M. rume* and *Clarias anguillaris – C. anguillaris*

Discussion

This study revealed that all the heavy metals analyzed were found in water, sediment and fish samples of Ajiwa irrigation Dam, Katsina. The results obtained showed that the water samples were lower in heavy metals concentration in line with reference values for USEPA, (2010). However, the sediments accumulated more heavy metal than the water and fish samples, these have also been observed by numerous researchers (Moruf and Akinjogunla, 2019; Akinjogunla and Lawal-Are, 2020; Akinjogunla et al, 2023) in some study areas. Sediment has been known to be the major depository of metals, holding more than 99% of total amount of a metal present in the aquatic system (Ozturk *et al*., 2009). According to Brady *et al*. (2015), these metal toxins act together with the sediment, to escalate to sequestration. Thus, excessive dilutions of these heavy metal contaminants are detected in sediment which now serves as a reservoir to these metallic ions (Brady *et al*. 2015; Bai *et al*. 2018).

The high levels of metals at surface water observed at wet season could be attributed to the combined effects of the effluents from the use of herbicides, and the mining products depots, which were discharged into the river close to that station; similar conclusion was drawn by Obasohan and Oronsaye (2000). Presence of zinc in water bodies such as Ajiwa dam could be associated with human activities such as the use of chemicals and zinc-based fertilizers by farmers (Egila and Nimyel, 2002). The levels of Zinc, Chromium and Cadmium recorded at all the stations during this investigation were lower than the maximum acceptable limits for aquatic life as recommended by WHO (2011). The presence of Lead may be due to surface runoffs and municipal waste discharges into the water bodies. The values obtained for Pb, Cr and Cd in the flesh, gills and intestine of the finfishes are in line with values reported by Wokoma (2011), where concentration of lead in tissue of *Psuedotolithus elongatus*, *Mugil cephalus* and *Chrisichthyes nigrodigitatus* from Sombreiro River located in Rivers State was 0.23mg/kg, 0.17mg/kg and 0.21 mg/kg respectively while Sambo *et al* (2014) reported the concentration of lead in the flesh of *Oreochromics niloticus* from Ibrahim Adamu Lake, Jigawa state, Nigeria as 0.27mg/kg and the level in the river sample as 0.81mg/l. Opaluwa *et al* (2012) reported the concentration of lead and cadmium from Uke Stream, Nasarawa State, Nigeria from different tissues of *Synodontis schall* respectively as 0.021mg/g and 0.005mg/g (head), 0.014mg.g and 0.015mg/g (gills), 0.011 mg/g and 0.026 mg/g (intestine) and 0.012 and 0.001 mg/g (flesh), while in *Clarias gariepinus*, the levels of lead and cadmium were respectively recorded as 0.031 mg/g and 0.005mg/g (head), 0.022 mg/g and 0.016mg/g (gills), 0.012mg/g and 0.025mg/g (intestine) and 0.013 mg/g and 0.001mg/g (flesh) and the corresponding water and sediment concentration were respectively recorded as 0.040mg/l and 0.095mg/g (lead) and 0.023 and 0.035mg/g (Cadmium).

The slight variation of values for the water and sediments between the findings in this study and those of previous reports could be attributed to the type of anthropogenic activities around the rivers studied, type of wastes deposited into the surface water and /or leached into the aquatic ecosystem through soil erosion.

The bioaccumulation potentials of different fish species as well as their level of tolerance could be a possible factor for the low concentration of these metals in the flesh of these species studied suggested that there may be little or no potential health hazard arising from their consumption with regard to Cadmium and Lead

The bio-accumulation factor (BWAF) values of the heavy metals analyzed in this study showed that bioaccumulation has occurred in the fish but not at an alarming rate as at the time of this study. Even though the fish samples are benthic feeder, their constant contact with the sediment does not affect its food intake to a great extent probably as a result of rapid remobilization of the adsorbed metals back into the surface waters through changes in some physicochemical parameters such as temperature, pH, and redox potentials. Also, the phenomenon that different metals are accumulated at different concentrations in the various organs of fish was

observed in this study. The variance in the level of deposits in the different organs and/or tissues of a fish can predominantly be accredited to the variations in the biological role of each organ, its comportment, regulatory ability, and feeding habits (Van der Oost et al., 2003).

For the fish organs examined, the gills have the highest concentration of all the metals, while the flesh recorded the least value and is thus the least preferred site for bioaccumulation. The high concentration of the metals in the gills could be due to element complexion with the mucus coverings in the gills which cannot be completely removed from the gill lamellae before analysis (Figueiredo-Fernandes et al., 2007). Another important influence in the total metal concentrations in the gills is the fact that metals get adsorbed onto the gills surface as the first target or point of contact for pollutants in water.

The concentrations of these heavy metals may be attributed to accumulation from the run-off of fertilizers and pesticides as well as runoff from the residential area and oil spillages from boats and canoes used at the dam (Chitou *et al*., 2021). The levels of metal in water bodies (lakes, rivers, lagoons) are mostly manipulated in the wet season by stormwater run- off from the environs on the water bodies' catchment and this ordinarily leads to a buildup in the metals. Islam *et al*. (2015) reported that metal concentration is expected to be low during the wet season due to the dilution effect on heavy metals but some site-specific activities and sources of metal contamination could lead to an exception to this general trend. Different trends of seasonal effects on heavy metal levels in water and sediments have been reported (Islam *et al*., 2015; Edokpayi *et al*., 2017; Le *et al*., 2020).

The results obtained from the assessment of these trace metals suggest that they may pose a potential toxicity problem due to the high clay content of the sediments which reduces drainage and increases the reduction of the metals. The continuous and regular intake of these finfishes collected from the Irrigation dam may likely induce health risks with regards to Cr, Pb and Cd intoxication. Although, WHO did not establish guidelines for Fe and Zn because they are not of health concern at levels found in drinking water, while Cr is an essential element that enhances the metabolism of carbohydrates, lipids and protein in humans (Udiba *et al*., 2020).

Conclusion

The study confirms that there was a significant presence of heavy metals in the commercially important finfishes collected from the Ajiwa irrigation dam. The bioaccumulation of some of these metals in the tissues of the finishes and water samples from the dam was within permissible/tolerable limits, indicating they are safe for consumption. The results obtained also revealed that the sediments accumulated metals at concentrations higher than the permissible limits. Continuous exposure of the dam to sources of these metals may pose a hazard to the end consumers (humans), as these finfishes will eventually absorb some of these metals into their edible tissue which is the main part of consumption for humans. Therefore, there is a need to regularly monitor organisms collected from these areas for metals accumulation.

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Detection of Tomato Yellow Ring Orthotospovirus in North Khorasan Province, Iran

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Abstract

Tomato is one of the most important vegetables in the world, cultivated both in the field and in greenhouses. Orthotospoviruses, are among the most economically important pathogens of tomato and cause significant damage to this crop worldwide. Tomato spotted wilt orthotospovirus (TSWV) and Tomato yellow ring orthotospovirus (TYRV) are two species of orthotospoviruses that have been described as potential threats to tomatoes worldwide. In a study of tomato infection in greenhouses in North Khorasan province (Bojnord) with Tomato yellow ring orthotospovirus, plants with symptoms of yellowing and necrosis of leaves and necrosis of stems were observed. Infection of these samples with TYRV was confirmed using test plants, DAS-ELISA, and reverse transcription (RT)-PCR. Infection of *Petunia hybrida* and *Chenopodium quinoa* with this virus was localized, while *Nicotiana benthamiana*, *N. glutinosa*, *Datura stramonium*, and Moneymaker tomato had systemic infection. Using DAS-ELISA and a specific antibody (prepared against the nucleocapsid protein) to detect TYRV, Iris yellow spot orthotospovirus, TSWV, Impatiens necrotic spot orthotospovirus, Groundnut bud necrosis orthotospovirus, Groundnut ring spot orthotospovirus, Tomato chlorotic spot orthotospovirus, and Chrysanthemum stem necrosis orthotospovirus, *N. benthamiana* plants with systemic infection were examined and confirmed to be infected with TYRV only. In the study of samples using RT-PCR, TYRV-specific primers and total RNA extracted from infected *N. benthamiana* leaves, a fragment of approximately 825 bp in size, which included the nucleocapsid protein gene, was amplified. This fragment was sequenced (HQ154131) and a study of amino acid sequence similarity in GenBank showed that the amino acid sequence of this fragment is 99% similar to the amino acid sequence of TYRV from Fars (ABH07703), Tehran (AAV98587), and Markazi (ACT09488) provinces in Iran. This is the first report of TYRV from North Khorasan province (Bojnord) in Iran.

Key Words: *TYRV, Orthotospovirus, Bojnord, Tomato*

Introduction

Tomato is one of the most consumed vegetables in the world due to its nutrients, minerals, and antioxidants (Du et al. 2017). The area harvested of tomato in the world and Iran in 2023 is reported to be approximately 5.4 million and 74,000 hectares, respectively. In 2023, based on the latest available data, China, India, Türkiye, the United States, and Egypt are the top five tomato producing countries in the world, accounting for more than 60% of global tomato production (FAO, 2023). Tomato production is for both domestic consumption and international trade, so it is available throughout the year (Caruso et al., 2022). Monoculture conditions of tomatoes cause the emergence of many pathogens, thus threatening the quantitative and qualitative yield of production (Hanssen et al., 2010l; Caruso et al., 2022). Tomato plants are susceptible to more than 200 diseases caused by different pathogens, both in the field and after harvest (Singh et al., 2017). Fungi, oomycetes, bacteria, phytoplasmas, viruses, and viroids cause the most important tomato diseases. Plant viruses, which are one of the main causes of diseases affecting food production worldwide, are estimated to have an economic impact of more than $30 billion per annum (Sastry & Zitter, 2014; Caruso et al., 2022). The genus *Orthotospovirus*, which belong to the family *Tospoviridae* and infect more than 1000 plant species of 82 families, cause serious damage to agriculture worldwide by infecting economically important plants (Wang et al., 2022). Yellow spots, mottling, wrinkle, withering, and even death are common symptoms of plants infected by the *Tospoviridae* family (Pappu et al., 2009). Thrips transmit members of the *Tospoviridae* family in a persistent manner (Oliver and Whitfield, 2016). These viruses have a wide host range. For example, *Tomato spotted wilt orthotospovirus* (TSWV) infects over 900 species belonging to more than 90 monocotyledonous and dicotyledonous plant families (Pappu et al., 2009, Wang et al., 2022). Orthopoviruses have been known to infect various plant species in Iran (Golnaraghi et al., 2001; Ghotbi et al., 2005; Beikzadeh et al., 2012b). The host range and geographic distribution of species of the genus *Orthopovirus* are increasing (Pappu et al., 2009) and in recent years, new species belonging to this genus have been proposed (Zarzynska-Nowak). One of these species is *Tomato yellow ring orthotospovirus* (TYRV), which was first identified on tomato in Iran (Hassani-Mehraban et al., 2005), and later detected in other plants such as potato, soybean, chrysanthemum, cineraria, gazania, anemone, and alstroemeria in Iran (Hassani-Mehraban et al., 2007; Rasoulpour and Izadpanah, 2007; Golnaraghi et al., 2008; Beikzadeh et al., 2012a; Mortazavi et al., 2013). The virus has also been reported

from Poland and Kenya (Birithia et al., 2012; Zarzyńska-Nowak et al., 2016) and has a wide host range, including ornamentals, weeds, and economically important crops in the Solanaceae and Fabaceae families. Tomato yellow ring orthotospovirus infects crops grown in the field and protected environments (Karavina, 2022). In most plants, this virus causes necrotic lesions on leaves and stems, which leads to a decrease in the quality and quantity of the products. On infected tomato fruits, bright yellow ring patterns are formed (Hassani-Mehraban et al., 2005). This study was conducted to detect this virus in tomato greenhouses in North Khorasan province, Iran.

Materials and Methods

During this study, greenhouse-grown tomato plants with symptoms of yellowing and necrotic leaves resembling those associated with orthotopoviruses, were observed in North Khorasan province (Figure 1).



Figure 1. Symptoms of infection on tomato leaves

Fresh leaves of the infected plants were ground with cold 0.01M phosphate buffer (pH 7.0) containing 0.1% sodium sulfite. The plant sap was mechanically inoculated onto the test plants. The inoculated plants were maintained for one to two weeks under normal greenhouse conditions for symptom expression (Hassani-Mehraban et al., 2005). The symptomatic plants were tested by double antibody sandwich (DAS)-ELISA using polyclonal antisera (Wageningen university) against the eight of the most important orthotopoviruses: TYRV, TSWV, *Iris yellow spot orthotopovirus* (IYSV), *Impatiens necrotic spot orthotopovirus* (INSV), *Groundnut bud necrosis orthotopovirus* (GBNV), *Groundnut ringspot orthotopovirus* (GRSV), *Tomato chlorotic spot orthotopovirus* (TCSV), and *Chrysanthemum stem necrosis orthotopovirus* (CSNV). The absorbance of the yellow reaction mixture at 405 nm is then read using an ELISA plate reader (Clark and Adams, 1977; Williams et al., 2001; de Ávila et al., 1990). The presence of TYRV in ELISA-positive *Nicotiana benthamiana* plants with systemic symptoms was further confirmed by conventional reverse transcription (RT)-PCR using specific primer [N-start: 5'-ATGGCTACCGCACGAGTG-3'(F) and N-stop: 5'-TTAAAATGCATC-3'(R)] complementary to the N gene. The primer pair supposed to amplify about 825 bp fragment (Hassani-Mehraban et al., 2005). Total RNA was extracted from *N. benthamiana*-infected plants using Trizol reagent as recommended by the manufacturer's instructions (Invitrogen) and used as template for cDNA synthesis. PCR reactions were performed by pre-heating at 94ºC for 5 min followed by 30 cycles of 30 sec of denaturation at 92ºC, 30 sec of annealing at 55ºC and 1 min for extension at 72ºC. Finally, the amplified DNA was incubated at 72ºC for 7 min to accomplish a final extension. The PCR reactions were subjected to electrophoresis in 1% agarose gel in TAE buffer and then stained with ethidium bromide (Pozzer et al., 1999; Eiras et al., 2001). The PCR product was purified (GFX™ PCR DNA and Gel Band Purification Kit; GE Healthcare UK Limited) and sequenced (Sanger et al., 1977). Sequence data were compared with those available in GenBank, using NCBI/BLAST, to search for related sequences.

Results

The results obtained from experimental host range studies by mechanical inoculation are summarized in Table 1. Systemic infection of inoculated *N. benthaminana* were confirmed using DAS-ELISA. Of the eight antibodies prepared against the N protein of different orthotospoviruses used in this test, the TYRV antibody reacted positively with extracts prepared from *N. benthaminana* samples (Figure 3). No positive reactions were observed with antibodies to other orthotospoviruses.

The infection of *N. benthamiana* with TYRV was confirmed using PCR. In the PCR test using primers designed based on the N gene of this virus, this gene was amplified and after electrophoresis in agarose gel, a DNA fragment of about 825 bp was observed. No band was observed in the negative control (healthy) sample (Figure 4).

Symptoms observed on the collected samples included yellowing and necrosis of tomato leaves. The characteristic symptoms of plant infection with orthotospoviruses are usually diverse and include chlorotic and necrotic lesions, mottling, leaf deformation, systemic necrosis, vein yellowing, and ringspot (Peters and Goldbach, 1995; Kritzman et al., 2001; Ghent et al., 2004; Ghent et al., 2006). The collected tomato samples showed symptoms similar to those of orthotospoviruses infection. These samples were identified as infected with orthotospoviruses using host range, serology, and polymerase chain reaction tests.

Table 1. Reaction of several host plants to virus infecting tomato after mechanical inoculation.

Test Plant	Symptoms	
	local	systemic
Petunia hybrida	NL	–
Nicotiana benthamiana	CS	Mo, LD, LN
Datura stramonium	CS	Mo, NS
Chenopodium quinoa	NL	–
N. glutinosa	NS	NS
Moneymaker tomato	NS	LY, LN

CS: chlorotic spot, LD: leaf deformation, LN: leaf necrosis, LY: leaf yellowing Mo: mottling, NL: necrotic lesion, NS: necrotic spot, -: no reaction

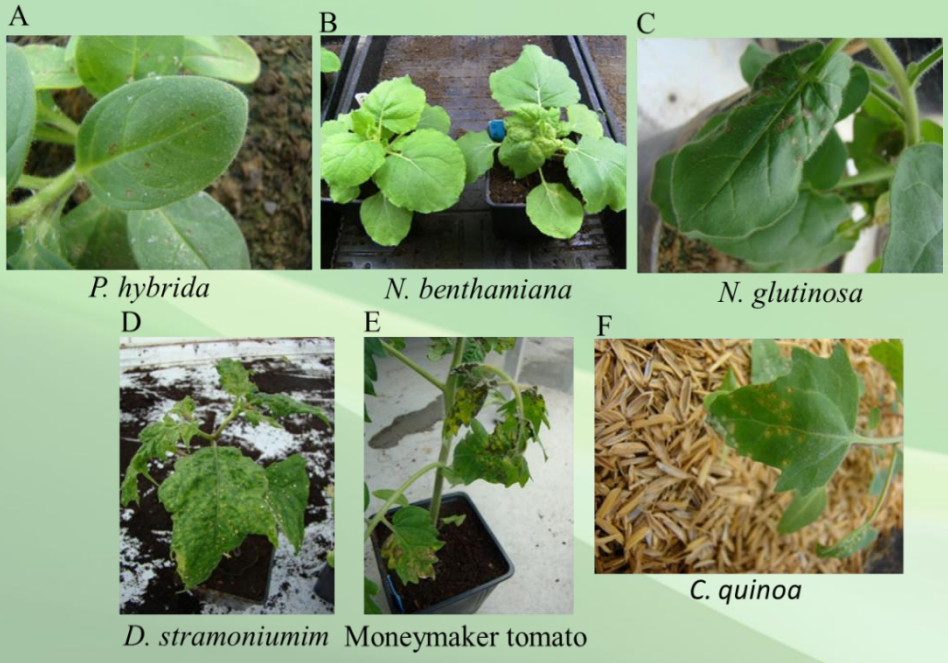


Figure 2. Symptoms of infection on test plants

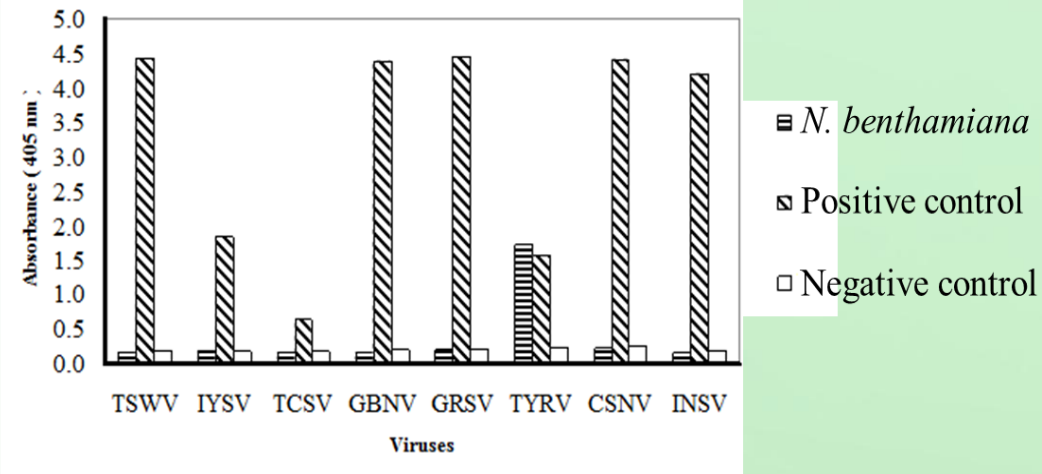


Figure 3. Mean absorbance of *N. benthaminana* sample, positive and negative controls at 405 nm

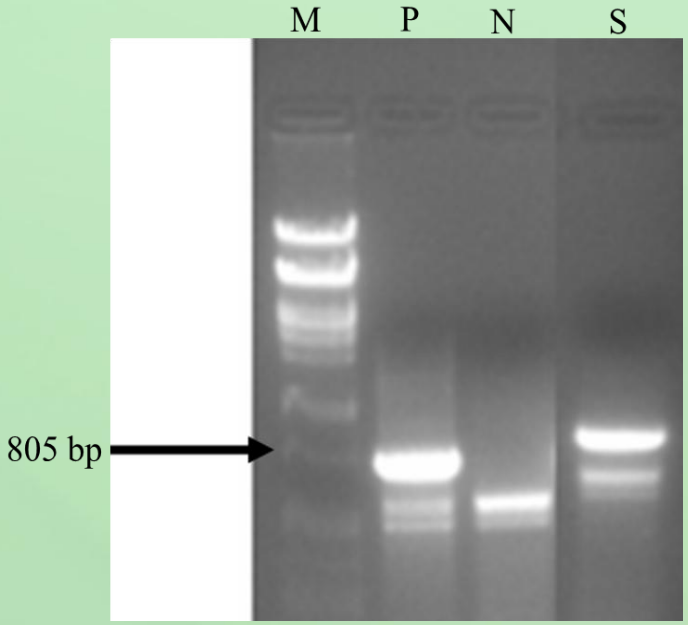


Figure 4. PCR result (M: marker, P: positive control, N: negative control, S: *N. benthamiana*)

Discussion

Host range studies showed that the tomato pathogen is mechanically transmitted. Symptoms of infection on *Petunia hybrida* and *C. quinoa* appeared as localized necrotic spots, while on *N. benthamiana*, *N. glutinosa*, *D. stramoniumim* and Moneymaker tomato they were systemic (Figure 2). Therefore, symptomatology and host range indicates that the samples examined were infected with an orthotospovirus and our results are consistent with several prior studies (Bezerra et al., 1999; Hassani-Mehraban et al., 2005; Rasoulpour & Izadpanah, 2007; Dong et al., 2008; Zheng et al., 2008; Ciuffo et al., 2009; Hassani-Mehraban et al., 2010).

The N-start primer is identical to the first 18 nucleotides of the N gene of TYRV from Iran with accession number AY686718, and the N-stop primer is complementary to the last 12 nucleotides of this gene in this virus. This gene has 825 nucleotides (Hassani-Mehraban et al., 2005), so it is expected that a fragment of 825 bp will be amplified in the PCR test. The amino acid sequence of the N protein reported in this study has been submitted to GenBank under Acc. No. HQ154131. A BLAST search showed that this fragment had 99% identity to TYRV from Markazi (GenBank Acc. No. ACT09488) and Fars (GenBank Acc. No. ABH07703) provinces and TYRV-t from Tehran (GenBank Acc. No. AAV98587) province in Iran. Since the amino acid sequence similarity of the N protein between a new virus and other confirmed orthotospoviruses must be less than 90% to be confirmed as a new species (de Ávila et al., 1990), the isolate examined in this study is not a new species and is confirmed as a Tomato yellow ring orthotopovirus solate based on the amino acid sequence similarity of the N protein.

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Climate change and livestock production in Africa

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Abstract

Climate change presents severe global challenges, with regions like Africa experiencing long-term shifts in temperature, precipitation, and wind patterns. Over the past two decades, rising surface temperatures and sea levels have been key indicators of this change, significantly affecting livestock production, a vital sector for rural livelihoods. Livestock farming, which relies on climate and natural resources, is particularly vulnerable, with rural farmers facing considerable risks despite its crucial role in food security and income. Studies on climate change's effects on livestock productivity emphasise the importance of temperature and precipitation, noting that higher temperatures typically reduce productivity, while droughts caused by reduced rainfall further exacerbate the challenges. On the other hand, increased rainfall benefits livestock by improving water availability and forage growth. Recent studies indicate that climate change negatively impacts livestock at the microeconomic level. However, the complexities of these effects, particularly the influence of socioeconomic factors such as market volatility, population growth, and conflicts, have not been thoroughly explored. As the climate crisis escalates, reliable data and effective adaptation strategies become increasingly important to mitigate these risks and ensure the long-term sustainability of livestock farming in Africa. Therefore, this study aims to study climate change and African livestock production. It is essential to expand research to include underrepresented livestock regions. Effective responses to climate change must be context-specific and holistic, with a more diversified focus addressing the impacts on non-ruminant livestock. It is crucial to conduct more research on the effects of climate change on livestock in some detail to develop practical solutions that support the resilience of rural livestock communities in Africa.

Key Words:

Introduction

Climate change continues to be a significant concern globally, posing risks to peace and economic stability. The Intergovernmental Panel on Climate Change (IPCC) predicts that global average surface temperatures will rise soon, while rainfall patterns have grown more unpredictable. In Africa, data from the World Meteorological Organization and the IPCC reveal that the continent has experienced the highest increase in average surface temperatures worldwide (IPCC, 2022). Climate change is emerging as a critical global developmental issue, with SSA expected to face particularly severe effects due to limited resources and adaptive capacity. These impacts are evident in extreme events like floods, storms, heat waves, and droughts (Archer et al., 2021). In South Africa, climate models suggest that temperatures could rise between 5°C and 8°C by 2050, with projections of more hot days, fewer cold spells, reduced overall rainfall, and potentially increased rain along the southern coast. Agriculture, which depends on stable climate conditions, is especially vulnerable to these changes. Given its role in contributing about 3% to South Africa's GDP, any agricultural disruption significantly impacts the economy (Nyoni et al., 2022). Furthermore, over 80% of the land in South Africa is non-arable and better suited for livestock farming, which supports the livelihoods of many rural and landless communities (Vetter et al., 2020). The country has a rich diversity of livestock, with approximately 12.8 million cattle, 19 million sheep, 1.8 million goats, and 1.5 million pigs. However, climate change's effects on livestock—such as higher death rates, slower growth, and reduced milk production—are causing serious challenges for South African livestock farmers (Maluleke et al., 2020). Due to the scarcity of land for new agricultural projects and increasing concerns over deforestation and climate change (Bagdatlı & Belliturk, 2016), temperature and precipitation are considered the most critical climatic factors and extreme events (Nasreldin and Elsheikh, 2022). Seasonal temperature fluctuations are slight; however, there is a significant decline in precipitation and the rainy season's length (Elsheikh, 2021; Elsheikh et al., 2022a). In South Africa, farmers with limited resources manage over half of the livestock population within smallholder traditional farming systems. These systems mainly support unemployed and retired individuals and children who benefit from selling livestock and animal products such as meat and milk. Although livestock farming is vital in enhancing the livelihoods of low-income populations, it operates under challenging environmental conditions that often limit productivity (Musemwa et al., 2012). Strengthening the resilience and efficiency of communal livestock systems is crucial for sustainable production and reducing food insecurity (Elsheikh et al., 2023; Bagdatlı et al., 2023). Livestock also has the potential to enhance climate resilience, often being more adaptable to changing

conditions than crop-based systems. However, to improve livestock's resilience, a deeper understanding of how climate change affects rural farming communities is essential (Maluleke et al., 2020). Effective policies and practices require detailed, sector-specific data on the range and scale of climate impacts, as these vary among livestock systems. Understanding these variations is vital to creating policies and interventions well-suited to specific needs (Archer et al., 2021). Coordinating climate impact knowledge and adaptation efforts across different levels helps identify shared challenges and fosters collaboration among production systems (Elsheikh et al., 2024). Additionally, gaps in research on climate adaptation in rural livestock production limit the sector's ability to anticipate and respond to climate impacts and track progress in adaptation efforts over time (Maluleke et al., 2020). Assessing the effects of climate change on various components of the water cycle is crucial for managing this essential resource, as water availability is increasingly strained due to growing societal demand (Elsheikh et al., 2022b; Bagdatlı & Arslan, 2019; Bagdatlı & Can, 2019).

While the livestock sector in Africa is highly complex, research on climate change's impact on rural communities has lagged compared to studies on crop production, and available evidence remains fragmented. Consistent data on climate-related damages and losses in the livestock sector is threatened. Livestock data is inherently challenging due to diverse production systems, agro-ecological zones, and differing production goals. Moreover, practices across livestock systems vary widely, shaped by cultural, socioeconomic, and institutional factors. Given its wide-ranging socio-economic and cultural benefits, livestock's role in Africa's development agenda is crucial. Despite ongoing efforts, climate change threatens rural livestock production, demanding urgent action (Zhou et al., 2022). This study seeks to address these knowledge gaps by systematically reviewing existing literature on climate change's effects on livestock production and pinpointing gaps that hinder effective adaptation strategies in rural South Africa and Sub-Saharan Africa (SSA) communities.

Climate change and livestock production in Africa

South Africa

Concerns around global climate change are escalating worldwide, with no country spared from its impacts, though vulnerability varies across regions. South Africa faces this challenge, with climate change marked by long-term temperature, precipitation, and wind patterns shifts. Over the last two decades, rising surface temperatures and sea levels have been central indicators of this change. Among agricultural sectors, livestock is particularly vulnerable due to its dependence on climate and natural resources, making rural livestock farming highly risky despite its importance for socio-economic livelihoods in rural areas. This growing climate impact on livestock has captured the attention of researchers, policymakers, and activists in South Africa (Zhou et al., 2022).

The livestock production sector in South Africa is highly vulnerable to climate risks, with both past and ongoing case studies highlighting the severity of these impacts. In the Suid Bokkeveld, an arid region in western South Africa where livestock is a primary source of income for most farmers, a participatory research study investigated the effects of climatic risks on small livestock. The study included weekly condition assessments, behavioral observations, and weather data measurements. The findings revealed significant lamb mortality due to cold conditions and a loss of condition during the dry season, primarily in summer. However, there is some overlap with cross-over summer rainfall (Archer et al., 2021). In the Limpopo region, Stroebel et al. (2011) observed that the impacts of drought were particularly evident in cattle herds, including significant effects on herd health and size. The study specifically focused on whether to cull or sell cattle, finding that such decisions are complex and influenced by how cattle are viewed and valued. Understanding these factors is crucial for making recommendations on managing cattle herd sizes in response to climatic risks.

The available literature highlights the importance of livestock to resource-limited communities, stressing the urgency for adaptation strategies to counter climate risks. Analysis of studies on climate shocks and adaptive responses is crucial for pinpointing priority areas within livestock production that need immediate action. The impact of climate change on rural livestock has gained significant attention since the 2000s, especially after a severe El Niño event triggered one of South Africa's worst droughts in 35 years, leading to disaster declarations in eight provinces. Public debates and policy discussions at all levels intensified as rural livestock farmers faced substantial production and financial losses exacerbated by the drought (Zhou et al., 2022).

From 2013 to early 2016, seven of South Africa's nine provinces reported a 14.4% decline in cattle herds due to climate stress (Maluleke & Mokwena, 2017). Farmers' debts rose by 9%, and feed costs skyrocketed by 177% as farmers struggled to sustain their core herds, many relying on costly feed purchases. Drought forecasting challenges and the reluctance to sell livestock assets further complicated the situation, with poor body conditions and market saturation resulting in low prices, unsold animals, and increased deaths. Predicting climate change risks remains complex, with climatic, ecological, and socio-economic factors influencing livestock losses. The scarcity and reliability of current data on climate effects in communal livestock farming are under scrutiny as climate scientists and policymakers seek more comprehensive and dependable information (Taruvinga et al., 2013).

Sub-Saharan Africa

Livestock production is essential for sustaining populations and diversifying rural communities, helping them cope with declining crop yields. However, recent crises—such as the COVID-19 pandemic and the Russo-Ukrainian war—pose additional threats to livestock production across Sub-Saharan Africa, compounding the adverse effects of climate change. COVID-19 restrictions, including social distancing and lockdowns, limited access to livestock markets, driving up production and feed costs for farmers unable to sell their livestock. The pandemic also restricted access to essential animal feed, veterinary care, and reproductive supplies, all critical for livestock production (FAO, 2020). Furthermore, the Russo-Ukrainian conflict has driven up wheat prices, affecting livestock feed costs and, subsequently, the quality and cost of beef production, as wheat is a primary feed ingredient (Ateba Boyomo et al., 2024).

Animal welfare and production ecology are valuable for analyzing climate change's effects on livestock production. Empirically, studies have shown climate change's negative impacts on livestock at the microeconomic level. However, these studies have limitations. For instance, while Emediegwu and Ubabukoh (2023) identify climate change transmission channels—such as maize prices, water scarcity, agricultural output, and conflict—they do not empirically test these factors. Additionally, the empirical literature on climate change has established that two-way fixed-effects panel data models are preferable to fixed-effects models, as they address omitted variable issues and reduce unobserved heterogeneity among individuals within a dataset (Ateba Boyomo et al., 2024).

Godde et al. (2021) highlight the significant influence of climate change on livestock production. Studies like Habte et al. (2022) and Emediegwu and Ubabukoh (2023) show that rising temperatures negatively impact livestock production in Sub-Saharan Africa, while research by Feng et al. (2021) reveals a positive correlation between rainfall and livestock productivity. Increased rainfall supports livestock production by ensuring animal water availability and forage growth, boosting productivity. Conversely, in Africa, reduced precipitation—and consequently, lower water availability—leads to declining livestock production, a pattern mirrored by the effects of rising temperatures, as drought often results from reduced rainfall. The World Meteorological Organization (WMO, 2022) confirms drought's severe impact on livestock in the Horn of Africa, including countries like Ethiopia, Kenya, and Somalia.

According to Mbow et al. (2019), increased volatility in cereal prices leads to reduced livestock production. The FAO's May 2022 quarterly bulletin supports this, reporting a 12.6% rise in food prices in West and Central Africa from February to March 2022. This increase is attributed to reduced wheat production in the drought-prone Sahel and the effects of the Ukraine conflict. Additionally, studies like Aragón et al. (2021) show that agricultural productivity positively affects livestock production. However, as Rehman et al. (2017) point out, population growth can reduce livestock production due to rapid urbanisation and demographic pressures across Africa, where climate shocks, conflicts, and tropical diseases worsen livestock scarcity.

Conclusion

With the right adaptation strategies, livestock can play a significant role in food security and sustainable development. Climate change is now a pressing challenge, particularly for underprivileged rural populations who rely directly on livestock for survival. The study suggests expanding research to cover more geographic areas and including non-ruminant species affected by different climate stresses. To respond effectively to climate impacts, mitigation strategies should be context-specific and holistic, aiming to enhance livestock production within rural farming communities.

Drought, a primary climate stressor, has prompted adaptive strategies like destocking, supplementary feeding, breed improvements, and diversification efforts. Expanding research to cover underrepresented livestock regions is essential. Effective climate change responses must be tailored and comprehensive, with more diversified research to include the effects on non-ruminant livestock. This paper emphasizes that response capacities will likely be underestimated without clarity on the extent of climate impacts. Additional focused research on adaptation and mitigation is crucial to creating practical solutions for rural livestock communities.

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Production and Quality Evaluation of Artisan Spaghetti Incoporated with Xanthan Gum and Eggs

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Abstract

Locally processed spaghetti is often associated with low mechanical strength and proximate composition. Xanthan gum (XG) and eggs are used by food industries to improve textural properties and nutritional value of foods. Locally processed spaghetti from three different formulation of wheat flour dough consisting XG and egg (3g, 50ml; 2.5g, 40ml; 2g, 30ml) and control sample with neither XG nor egg were produced. The effects of XG and egg on textural properties, proximate composition, and sensory attributes of the spaghetti were analyzed. Proximate composition were determined using standard methods, texture of dry spaghetti was evaluated using fracturability test method, while for the cooked spaghetti texture analyzer machine was used. The sensory profile was investigated using 9-point hedonic scale method. The results showed that incorporating xanthan gum and egg to wheat flour during dough formation significantly modified the properties of the processed spaghetti. There was increased in protein (26.17%), and fat contents (8.07%) compared to the control spaghetti. Sample with higher XG and gum exhibit more hardness (19.01%), cohesiveness (1.39%), and fracturability (78.11%). XG improved mechanical strength of the dried spaghetti, hardness (19.01%), cohesiveness (1.39%), and fracturability (78.11%) compared to other samples. However, sensory evaluation highlighted a need to manage the aroma due to the eggy smell. This research highlights the potential of xanthan gum and egg as functional additives to enhance the quality, textural and sensory properties of locally processed spaghetti. The findings provide a foundation for scaling up production and improving the competitiveness of local pasta producers in the market.

Key Words: *Xanthan Gum, Egg, Spaghetti quality and Textural characteristics*

ID: 321

Determination of in vitro Antagonistic Activity of Burkholderia ambifaria against Fungal Storage Diseases in Citrus Fruits

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Abstract

Postharvest fungal diseases in mandarin fruits cause significant economic and nutritional losses during transport and storage. The control of postharvest diseases in citrus fruit involves frequent and large amounts of chemical fungicides. Increasing concerns about health hazards and environmental pollution caused by the use of chemicals have necessitated the development and use of environmentally friendly control strategies as an alternative to chemicals for the control of post-harvest diseases in citrus fruits. The bacterial isolates as biological control agents (BCAs) are one of the most suitable alternatives to synthetic fungicides, which are banned or restricted for use in post-harvest disease management. Fungal diseases such as black mould (*Aspergillus niger*), blue mould (*Penicillium italicum*), green mould (*Penicillium digitatum*), sour rot (*Geotrichum citri-aurantii*), and anthracnose (*Colletotrichum gloeosporioides*) cause the most significant postharvest losses in citrus fruit. The BCA bacterial isolate used in this study was isolated from healthy mandarins and identified as *Burkholderia ambifaria* by Matrix Assisted Laser Desorption Ionisation Time of Flight-Mass Spectrometry (MALDI TOF MS; MicroFlex LT, Bruker Daltonics, Bremen, Germany) analysis. In this study, the antagonistic activity of *B. ambifaria* on the inhibition of mycelial growth of *A niger, P. italicum, P. digitatum, G. citri-aurantii* and *C. gloeosporioides* isolated from mandarin fruits was determined *in vitro* conditions. In dual culture tests, the BCA *B. ambifaria* isolate inhibited the mycelial growth of *C. gloeosporioides* by 66.67%, *A. niger* by 69.40%, *G. citri-aurantii* by 73.33%, *P. italicum* and *P. digitatum* by 77.78%. The high level of antagonistic activity of the bacterial isolate in inhibiting the mycelial growth of fungal pathogens showed that the *B. ambifaria* has the potential to be used as a BCA against diseases occurring during post-harvest storage.

Key Words: *Citrus; Biological control; Burkholderia ambifaria, MALDI TOF MS*

ID: 322

Sustainable Cowpea (*Vigna unguiculata* L.Walp) Production as Impacted by Integrated Weed Management Practices

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Abstract

Field trials were conducted over two consecutive growing seasons at the Research and Teaching farm of the Faculty of Agriculture, Bayero University Kano (Latitude 11° 58 N, Longitude 8° 25 E; altitude 458 m als). The efficacy of twelve different weed control treatments using various herbicides alone, in combination, or in addition to hoe weeding was evaluated on cowpea (var. IT99K-573-1-1) in a randomized complete block design (RCBD) with three replications. The treatments comprised of weedy check (control), hoe weeding at 3 & 6 weeks after sowing (WAS), metolachlor at 2.0 kg a.i.ha^{-1}, imazethapyr at 3.0 kg a.i.ha^{-1}, pendimethalin at 2.0 kg a.i. ha^{-1}, pendimethalin at 3.0 kg a.i. ha^{-1}, pendimethalin 1.0 + imazethapyr 1.0 kg a.i.ha^{-1}, metolachlor 1.5 + pendimethalin 1.5 kg a.i.ha^{-1}, imazethapyr 1.0 + pendimethalin 1.0 kg a.i.ha^{-1} + SHW at 6 WAS, metolachlor 1.5 + pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS, metolachlor at 2.0 + SHW at 6 WAS, and pendimethalin at 2.0 + SHW at 6 WAS. Data were collected on cowpea growth, yield, and weed management parameters and were subjected to analysis of variance (ANOVA), and treatment means were compared using the Student Newman-Keuls test (SNK) at a 5% level of probability. Results indicated that weed control significantly ($p < 0.001$) influenced crop growth and yield. Herbicide treatments, particularly those involving pendimethalin, imazethapyr, and metolachlor, effectively suppressed weed growth, leading to increased plant height (101.9-147.9 cm), leaf area (44.87-47.93 cm^2), and number of leaves (113.17-122.03). Additionally, these treatments resulted in a higher number of pods (74.47-77.10) and seed yields (702.0-705.5 kg ha^{-1}) compared to the weedy check. Findings further revealed that the combination of herbicides with hoe weeding proved to be the most effective strategy, providing superior weed control and maximizing crop productivity. These findings highlight the importance of integrated weed management practices for sustainable cowpea production.

Key Words: *cowpea, integrated weed management, sustainable, weed control index*

Introduction

Cowpea (*Vigna unguiculata* L. Walp; Fabaceae) is a vital legume with widespread cultivation in Nigeria, playing a pivotal role in both subsistence farming and commercial agriculture. Its resilience to drought conditions and ability to thrive in nutrient-poor soils have established it as a valuable crop, particularly in regions facing these challenges (Ojo *et al*., 2018; Adediran *et al*., 2021). In recent years, the sustainable management of weeds in cowpea production systems has become a significant agricultural challenge in Nigeria.

The expected yield of the crop is considerably diminished by biotic and abiotic stresses, including edaphic factors, drought, cultivar selection, pest and disease infestations, with infestations by weeds being a significant contributor (Liliane and Charles, 2020; Anwar *et al*., 2021; Skendžić *et al.,* 2023). Uncontrolled weed infestation has been reported to cause a 90% reduction in the yield of cowpea (de Campos *et al*., 2023). Among the methods available for checkmating the weed infestation in cropping systems, chemical methods using preemergent herbicides are preferred due to efficiency, selectivity, and reduced drudgery. However, pre-emergence therapies alone are inadequate for preventing weed flushes through the rainy season, thus needing post-emergence therapy following pre-emergence control (Shittu, 2023; Shittu et al., Shittu and Bassey, 2023; Shittu and Lamarana, 2024).

The excessive use of herbicides has led to a myriad of environmental concerns, including water pollution, biodiversity loss, and the emergence of herbicide-resistant weeds (Nwafor *et al*., 2018; Nath *et al*., 2024). These adverse consequences necessitate the exploration of alternative weed control strategies. Addressing these challenges is crucial to ensuring the sustainability of cowpea production, particularly in the face of climate change and increasing global food demands. Integrated weed management (IWM) has emerged as a promising approach to address these challenges. IWM is a holistic strategy that combines various methods to control weeds while minimizing negative impacts on the environment and agricultural productivity. By integrating cultural, biological, and chemical control measures, IWM aims to create a more sustainable and resilient agricultural system (Olowe *et al*., 2020; Adebayo *et al*., 2022).

Additionally, combining cultural practices such as supplementary hoe weeding to broaden the spectrum efficacy of the preemergence herbicide will greatly enhances weed suppression and improves grain yield of cowpea. Thus, the study evaluated herbicide treatments and hoe weeding in Nigeria's cowpea farming system, aiming to improve weed control and crop yield using an integrated approach. The research aimed to determine the optimal combination of herbicides for sustainable weed management, influencing the development of more effective practices in a sustainable manner in the Sudano- Sahelian region of Nigeria.

Materials And Methods

The experiments were conducted during 2019 and 2020 rainy season at the Research and Teaching farm of the Faculty of Agriculture, Bayero University Kano (Latitude 11° 58 N, Longitude 8° 25 E; altitude 458 m als), in a randomized complete block design (RCBD) with three replicates. The soil at the experimental site was sandy loam with low accessible N (0.06 g kg^{-1}), low levels of P (4.87 g kg^{-1}) and medium levels of K (0.32 g kg^{-1}). The gross plot was 3 x 4.5 m (12 m^2) which is made up of six ridges (rows) while the net plot size was 1.5 m x 3 m (4.5 m^2) comprising the two inner rows with an alley of 0.5 m and 1.0 m between the plots and replications, respectively. The effectiveness of twelve different weed control treatments using various herbicides alone, in combination, or in addition to hoe weeding on cowpea (var. IT99K-573-1-1) was assessed. Every year, the crop was sown in the first week of July at a seed rate of 75 kg ha^{-1}, and treated two weeks later with NPK (15:15:15) and SSP (18%) at a rate of 20 kg N, 40 kg P_2O_5, and 20 kg K_2O ha^{-1}. The SSP was however applied during land preparation. Herbicidal treatments were applied as per treatment. The details of the treatments were as follows: weedy check (control), hoe weeding at 3 & 6 weeks after sowing (WAS), metolachlor at 2.0 kg a.i.ha^{-1}, imazethapyr at 3.0 kg a.i.ha^{-1}, pendimethalin at 2.0 kg a.i. ha^{-1}, pendimethalin at 3.0 kg a.i ha^{-1}, pendimethalin 1.0 + imazethapyr 1.0 kg a.i.ha^{-1}, metolachlor 1.5 + pendimethalin 1.5 kg a.i.ha^{-1}, imazethapyr 1.0 + pendimethalin 1.0 kg a.i.ha^{-1} + SHW at 6 WAS, metolachlor 1.5 + pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS, metolachlor at 2.0 + SHW at 6 WAS, pendimethalin at 2.0 + SHW at 6 WAS. The herbicidal treatments either alone or in mixture were applied pre-emergence on the tested crop. Data were collected on weed attributes, crop growth and yield related characters which were subjected to analysis of variance (ANOVA) and treatment means were separated using Student Newman-Keuls-test (SNK) at 5% level of probability.

Results And Discussion

Crop Injury Scores and crop vigor

Table 1 presents the effect of weed control methods on crop injury score and crop vigor of cowpea during the 2019 and 2020 seasons and the combined. Results show that the weedy check and the plots that received hoe weeding at 3 and 6 WAS consistently resulted in the lower injury score compared to all other herbicidal treatments, either alone or integrated with hoe weeding at 6 WAS or tank mixture that resulted in slightly higher injury scores during the 2019 and 2020 rainy seasons and the combined. On the other hand, weedy check plots had significantly ($p < 0.001$) the lowest crop vigor scores compared to all other treatments across all seasons combined. The highly significant crop injury scores obtained between treatments, including the weedy check, are a positive finding. This aligns with research by Ribeiro Junior *et al.* (2018), who found that herbicides, when applied according to recommended rates and timings, generally cause minimal to no injury to cowpea plants. This suggests that the weed control methods tested in this study were safe for cowpea at the observed time (6 WAS), and it is highly selective to the crop. Similar findings were reported by Pedroso *et al.* (2020) and Correia and Carvalho (2021) in soybean and sweet potato, respectively.

Similarly, the clear distinction between treatments in terms of crop vigor is noteworthy. Weedy check plots consistently resulted in the lowest vigor scores compared to other treatments that resulted in statistically comparably higher vigor scores. This suggests that hoe weeding at 3 and 6 WAS and other herbicidal treatments provided the most effective weed control, allowing the cowpea plants to thrive with minimal competition for growth resources. The similar vigor scores observed with Imazethapyr, Pendimethalin, and some herbicide combinations compared to hoe weeding are promising. These findings align with studies by Anna Bárbara de *et al*. (2020) and Sinchana and Raj (2020), who reported that Imazethapyr and Pendimethalin effectively controlled weeds in cowpea, leading to improved crop growth and yield. Thus, these herbicidal treatment combinations may offer valuable alternatives to hoe weeding, particularly in situations where manual labor is limited.

Plant height and Number of Leaves

The impact of various weed control treatments on plant height and number of leaves of cowpea at 9 WAS across two growing seasons (2019 and 2020) and the combined is shown in Table 2. There was no significant ($P > 0.05$) variation in plant height during the 2019 and 2020 seasons. However, the weedy check plots resulted in the shortest plants, while all other treatments were not statistically comparable and taller when the seasons were combined. The observed significant differences in plant height between treatments highlighted the importance of weed control for cowpea growth. This corroborates the findings of Sinchana and Raj (2020), who reported that weed competition significantly reduced cowpea plant height compared to weed-free plots. The tallest plants were observed in the imazethapyr + pendimethalin

(1.0 + 1.0 kg a.i.ha^{-1} + SHW) treatment, followed by the pendimethalin (2.0 kg a.i.ha^{-1} + SHW) treatment. This suggests that these herbicide combinations, particularly when combined with SHW, were highly effective in controlling weeds, allowing cowpea plants to grow taller with less competition for growth resources. Conversely, the weedy check plots and plots treated solely with pre-emergence herbicide had statistically similar plant heights, indicating potential growth suppression due to unchecked weed competition that occurs later in the growing season. This finding agreed with those of Shittu (2023), Shittu and Bassey (2023), Shittu *et al.* (2023), and Shittu *et al.* (2024), who reported separately the inability of pre-emergence alone to provide season-long weed control in comparison with plots that received supplementary hoe weeding at 6 WAS or post-emergent herbicide, which cumulatively increase the efficacy of the weed control treatments in tomato, cowpea, and roselle and cucumber, respectively. Similarly, the weedy check plots had the lowest number of leaves ($P < 0.001$) when the years were combined, but plots treated with Pendimethalin at 2.0 kg a.i. ha^{-1} *fb* hoe weeding at 6 WAS recorded the highest number of leaves per plant, although at par with other treatments.

Table 1. Crop injury score and Crop vigor score of cowpeas as influenced by Weed control treatments during 2019 and 2020 rainy season

Treatment	Crop injury scores @ 6 WAS			Crop vigor scores @ 9 WAS		
	2019	2020	Combined	2019	2020	Combined
Weedy check	0.00d	0.00f	0.00d	5.33b	7.00b	6.17e
Hoe weeding at 3 and 6 WAS[1]	0.00d	0.00f	0.00d	9.00a	9.00a	9.00a
Metolachlor at 2.0 kg a.i.ha^{-1}	1.00ab	1.00bc	1.00c	8.33a	8.67a	8.50cd
Imazethapyr 3.0 kg a.i.ha^{-1}	1.33a	1.67ab	1.50abc	9.00a	9.00a	9.00ab
Pendimethalin 2.0 kg a.i.ha^{-1}	1.33a	2.33a	1.83ab	9.00a	9.00a	9.00ab
Pendimethalin 2.0 kg a.i.ha^{-1}	1.33a	2.33a	1.83a	8.67a	9.00a	8.84abc
Imazethapyr 1.0 + Pendimethalin 1.0 kg a.i.ha^{-1}	1.33a	1.00bc	1.17bc	8.67a	9.00a	8.84abc
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1}	1.00abc	1.00bc	1.00c	8.67a	8.67a	8.67abc
Imazethapyr 1.0 + Pendimethalin 1.0 0 kg a.i.ha^{-1} + SHW at 6 WAS[2]	1.00abc	1.00bcd	1.00c	9.00a	9.00a	9.00a
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	1.00abc	1.00b-e	1.00c	9.00a	9.00a	9.00a
Metolachlor 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	1.00abc	1.00b-e	1.00c	9.00a	9.00a	9.00a
Pendimethalin 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	1.33a	1.33b	1.33abc	9.00a	9.00a	9.00ab
P of F	0.001	<.001	<.001	<.001	0.006	<.001
SE±	0.2229	0.2546	0.1776	0.195	0.308	0.302

Means followed by the common letter (s) in a in column are not significantly different at 5% according to Student-Newman-Keuls Test (SNK). [1]WAS = weeks after sowing; [2]SHW= Supplementary hoe weeding.

Table 2: Plant height and Number of leaves per plant of cowpea as influenced by Weed control treatments during 2019 and 2020 rainy season

Treatment	Plant height (cm) @ 9 WAS			Number of leaves plant^{-1} @ 9 WAS		
	2019	2020	Combined	2019	2020	Combined
Weedy check	84.8	86.8	85.8b	66.83	74.97	70.90e
Hoe weeding at 3 and 6 WAS[1]	115.0	116.8	115.9ab	103.93	106.00	104.97abc
Metolachlor at 2.0 kg a.i.ha^{-1}	138.0	118.5	117.1ab	89.87	92.00	90.93bcd
Imazethapyr 3.0 kg a.i.ha^{-1}	100.4	103.4	101.9ab	80.40	82.53	81.47cd
Pendimethalin 2.0 kg a.i.ha^{-1}	103.4	105.4	104.4ab	89.62	93.52	91.57bcd
Pendimethalin 2.0 kg a.i.ha^{-1}	103.3	108.1	105.7ab	89.97	92.87	91.42bcd
Imazethapyr 1.0 + Pendimethalin 1.0 kg a.i.ha^{-1}	126.0	128.5	127.3ab	91.73	93.87	92.80bcd
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1}	115.3	128.5	117.5ab	95.73	98.40	97.07a-d
Imazethapyr 1.0 + Pendimethalin 1.0 0 kg a.i.ha^{-1} + SHW at 6 WAS[2]	146.5	149.3	147.9a	113.67	112.67	113.17ab
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	139.3	105.4	141.1a	104.37	106.43	105.40abc
Metolachlor 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	99.6	102.6	101.1ab	110.97	111.53	111.25ab
Pendimethalin 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	138.0	136.3	137.1a	121.20	122.87	122.03a
P of F	0.406	0.361	0.004	0.070	0.142	<.001
SE±	17.88	17.05	10.79	10.53	10.39	6.50

Means followed by the common letter (s) in a in column are not significantly different at 5% according to Student-Newman-Keuls Test (SNK). [1]WAS = weeks after sowing; [2]SHW= Supplementary hoe weeding

Table 3. Leaf area and Laef area index of Cowpea as influenced by Weed control treatments during 2019 and 2020 rainy season

Treatment	Leaf area (cm^2) @ 9 WAS			Leaf area index @ 9 WAS		
	2019	2020	Combined	2019	2020	Combined
Weedy check	30.81f	34.00d	32.41e	1.05g	1.12c	1.09e
Hoe weeding at 3 and 6 WAS[1]	43.88ab	49.00a	45.94ab	1.85ab	2.24a	2.05a
Metolachlor at 2.0 kg a.i.ha^{-1}	36.07cde	37.45c	36.76d	1.47f	1.60b	1.53d
Imazethapyr 3.0 kg a.i.ha^{-1}	36.68bcd	39.57c	38.13cd	1.48f	1.65b	1.58cd
Pendimethalin 2.0 kg a.i.ha^{-1}	39.08abc	40.58bc	39.83cd	1.56cf	1.68b	1.60cd
Pendimethalin 2.0 kg a.i.ha^{-1}	40.28abc	41.22bc	40.75cd	1.60b-f	1.77ab	1.69bcd
Imazethapyr 1.0 + Pendimethalin 1.0 kg a.i.ha^{-1}	41.10abc	44.00ab	42.55bc	1.79a-e	1.89ab	1.84abc
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1}	44.42ab	45.32a	44.87ab	1.82a-d	2.00ab	1.91ab
Imazethapyr 1.0 + Pendimethalin 1.0 0 kg a.i.ha^{-1} + SHW at 6 WAS[2]	45.68a	47.97a	46.83ab	1.81a-d	2.04ab	1.93ab
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	46.42a	47.00a	46.71ab	1.82abc	2.06ab	1.94ab
Metolachlor 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	47.19a	48.33a	47.76a	1.90a	2.09ab	2.00a
Pendimethalin 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	46.86a	48.00a	47.93a	1.92a	2.11ab	2.017a
P of F	<.001	<.001	<.001	<.001	<.001	<.001
SE±	1.768	1.114	1.208	0.061	0.109	0.074

Means followed by the common letter (s) in a in column are not significantly different at 5% according to Student-Newman-Keuls Test (SNK). [1]WAS = weeks after sowing; [2]SHW= Supplementary hoe weeding

The findings on the number of leaves suggest a potential positive influence of this treatment on leaf production. It's possible that hoe weeding minimizes herbicide-plant contact, which reduces herbicide phytotoxicity, ultimately leading to less stress on the cowpea plants and allowing for better growth. This is inline with the findings of Galon *et al*. (2021), who reported the increase in growth characters of canola and suppression of weed growth. The lack of a significant difference in the 2019 and 2020 seasons could be due to environmental factors or require a longer observation period beyond 9 WAS to detect variations in leaf production between treatments.

Leaf Area and Leaf Area Index

Table 3 presents the influence of various weed control treatments on leaf area and leaf area index (LAI) of cowpea at 9 WAS across two growing seasons (2019 and 2020) and combined. The result demonstrated that the weedy check plots had the smallest leaves overall. In both years, several treatments significantly ($P < 0.001$) resulted in the larger leaves, including a combination of herbicide and hoe weeding. Overall, the application of pendimethalin and metolachlor, each at 2.0 kg a.i.ha^{-1} + SHW at WAS, the combination of imazethapyr + pendimethalin (1.0 + 1.0 kg a.i.ha^{-1}) + SHW at 6 WAS, and metolachlor + pendimethalin (1.5 + 1.5 kg a.i.ha^{-1} + SHW) significantly resulted in larger leaves, which were at par with other treatments in the 2019 season. A similar trend of results was equally observed during the 2020 season as well as the combined effect. This suggests that the treatments with hoe weeding were particularly effective in controlling weeds, allowing cowpea plants to develop larger leaves with less competition for light and other growth resources. Conversely, the weedy check plots had the lowest leaf area, indicating limitations on leaf growth likely due to weed competition. This aligns with research by Enejoh *et al*. (2018), who found that uncontrolled weeds significantly reduced cowpea leaf area compared to weed-free plots.
Similar to leaf area, the leaf area index (LAI) results showed significant differences between treatments, mirroring the trends observed with leaf area. LAI is a critical parameter reflecting the canopy's light interception capacity, which directly influences photosynthesis. The lower LAI observed in the weedy check plots suggests reduced light interception and potentially lower photosynthetic potential, ultimately impacting plant growth and yield. The result is consistent with those of Saberali *et al*. (2016) and Bisikwa *et al.* (2021), who found that weed competition dramatically lowered cowpea LAI, which in turn led to lower biomass output. As such, crop canopy expansion and competitiveness for solar radiation and production of dry matter can be enhanced by suppression of weed growth within the crop canopy as emphasized by Evers and Bastiaans (2016). Similarly, Ibitoye *et al*. (2020) reported that employing integrated weed management strategies involving hand weeding or mechanical weeding combined with herbicides resulted in a greater leaf area and LAI in cowpea compared to herbicide application alone, which might be attributed to increased spectrum activity of the pre-emergence herbicides to smother the growth of the late-emerging weeds.

Number of pods per plant and Number of seeds per pod

The influence of various weed control treatments on cowpea yield-related characters is presented in Table 4. Results revealed that the application of 2 HW at 3 and 6 WAS, Pendimethalin and Metolachlor, each at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS, significantly ($P < 0.001$) resulted in a higher number of pod plants, although at par with

other treatments compared to the weedy check that had lower values in the 2019 and 2020 seasons and the combine. On the other hand, the application of metolachlor at 2.0 kg a.i.ha^{-1} + SHW at 6 WAS significantly ($P < 0.001$) produced the highest number of seeds per pod, which was comparable with the rest of the treatments, although the weedy check resulted in a lower seed number per pod in both seasons and combined.

Table 4. Number of Pods per plant and Number of seeds per pod of Cowpea as influenced by Weed control treatments during 2019 and 2020 rainy season

Treatment	Number of pods plant^{-1}			Number of seeds pod^{-1}		
	2019	2020	Combined	2019	2020	Combined
Weedy check	42.47d	45.90d	44.18e	9.07b	10.13b	9.60c
Hoe weeding at 3 and 6 WAS[1]	76.37a	78.90a	77.63a	11.73ab	13.67ab	12.70ab
Metolachlor at 2.0 kg a.i.ha^{-1}	54.07c	56.20cd	55.13d	11.60ab	13.00ab	12.30ab
Imazethapyr 3.0 kg a.i.ha^{-1}	51.73c	53.77cde	52.75d	10.47ab	11.33ab	10.90bc
Pendimethalin 2.0 kg a.i.ha^{-1}	54.57c	57.37cd	55.97d	11.30ab	12.67ab	11.98ab
Pendimethalin 2.0 kg a.i.ha^{-1}	54.57c	52.47cd	53.78d	11.47ab	12.33ab	11.90ab
Imazethapyr 1.0 + Pendimethalin 1.0 kg a.i.ha^{-1}	54.94c	56.37cd	55.65d	10.40ab	11.33ab	10.87bc
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1}	62.10bc	64.43bc	63.27c	11.87a	13.00ab	12.43ab
Imazethapyr 1.0 + Pendimethalin 1.0 0 kg a.i.ha^{-1} + SHW at 6 WAS[2]	68.40ab	70.10ab	69.25b	11.13ab	12.33ab	11.73ab
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	64.78b	67.78ab	66.28bc	11.53ab	13.00ab	12.27ab
Metolachlor 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	74.47a	75.87a	75.17a	12.67a	14.33a	13.50a
Pendimethalin 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	75.10a	77.10a	76.10a	11.40ab	12.67ab	12.03ab
P of F	<.001	<.001	<.001	0.023	0.061	<.001
SE±	2.475	2.671	1.715	0.552	0.767	0.508

Means followed by the common letter (s) in a in column are not significantly different at 5% according to Student-Newman-Keuls Test (SNK). [1]WAS = weeks after sowing; [2]SHW= Supplementary hoe weeding

Table 5. Seed yield and 100 seed weight of cowpea as influenced by Weed control treatments during 2019 and 2020 rainy season

Treatment	Seed yield (kg ha^{-1})			Hundred seed weight (g)		
	2019	2020	Combined	2019	2020	Combined
Weedy check	301.3f	306.0f	303.7f	13.80c	14.95d	14.38b
Hoe weeding at 3 and 6 WAS[1]	699.3a	720.0a	709.7a	22.67a	20.97ab	21.82a
Metolachlor at 2.0 kg a.i.ha^{-1}	510.3e	525.7e	518.0e	18.50b	19.73abc	19.12a
Imazethapyr 3.0 kg a.i.ha^{-1}	520.0e	533.3ce	526.7e	18.47b	19.90ab	19.18a
Pendimethalin 2.0 kg a.i.ha^{-1}	560.3d	562.7cd	561.5d	18.97b	20.13ab	19.55a
Pendimethalin 2.0 kg a.i.ha^{-1}	564.7d	567.7c	566.2d	20.07b	21.47a	20.77a
Imazethapyr 1.0 + Pendimethalin 1.0 kg a.i.ha^{-1}	586.3c	634.0b	610.2c	19.20b	20.33ab	19.77a
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1}	593.7c	639.3b	616.5c	19.57b	20.83ab	20.20a
Imazethapyr 1.0 + Pendimethalin 1.0 0 kg a.i.ha^{-1} + SHW at 6 WAS[2]	649.0b	699.0a	674.0b	19.47b	21.07ab	20.27a
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	658.3b	698.7a	678.5ab	19.57b	20.83ab	20.20a
Metolachlor 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	688.0a	716.0a	702.0ab	20.87ab	22.07a	21.47a
Pendimethalin 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	693.3a	717.7a	705.5ab	21.47ab	22.60a	22.03a
P of F	<.001	<.001	<.001	<.001	0.050	<.001
SE±	6.07	9.99	8.74	0.661	1.304	0.731

Means followed by the common letter (s) in a in column are not significantly different at 5% according to Student-Newman-Keuls Test (SNK). [1]WAS = weeks after sowing; [2]SHW= Supplementary hoe weeding.

Seed Yield and Seed Quality

Table 5 examines the influence of various weed control treatments on cowpea seed yield and hundred seed weight (g) across two years (2019 and 2020) and combined data. The weedy check had the lowest yield across all years. Similar to Table 4, treatments including hand weeding resulted in significantly ($P < 0.001$) higher yields compared to their non-SHW counterparts. For the 2020 rainy season, hoe weeding alone, as well as when integrated with other herbicide treatments, showed the highest seed yield per plot; however, during the 2019 rainy season, hoe weeding alone showed the highest yield and was not statistically different from plots treated with metolachlor and pendimethalin, both at 2.0 kg a.i. ha^{-1}, and Imazethapyr + Pendimethalin, each 1.0 kg a.i. ha^{-1} + SHW at 6 WAS,

compared to other treatments that resulted in decreased seed yield, with the weedy check recording the lowest seed yield across both seasons and combined. The weedy check plots recorded the lowest 100 seed weights across all years and when the data was combined. The plots treated with hand weeding at 3 and 6 WAS recorded the highest seed weights and showed no statistical difference with plots treated with herbicide either alone or in combination with SHW at 6 WAS. The increase in seed yield and yield-related characters of cowpea achieved by the above treatments could be attributed to the efficacy of the second weeding applied to both hoe-weeded and herbicidal-treated plots, which is linked to its ability to suppress late-emerging weeds. This suppression enhances the plants' capacity to utilize available growth resources for photosynthate assimilation, ultimately increasing the production of dry matter allocated to sinks. This finding aligns with the reports of Adeyemi et al. (2019), Omovbude et al. (2020), Naeem et al. (2022), and Shittu et al. (2022), each of which documented the impact of supplementary hoe weeding on the effectiveness of pre-emergence herbicides in improving the productivity of maize, lowland rice, barley, and groundnut, respectively.

Weed characters

Table 6 reports the effects of different weed control treatments on weed cover score, weed index, and weed control index (WCI) of cowpea over two years (2019 and 2020) and the combined data. Weedy check plots consistently had the highest weed cover score and weed index and the lowest WCI across all years, indicating the most significant weed infestation. Performing hoe weeding at 3 and 6 WAS generally resulted in the lowest weed cover score and weed index, along with the highest WCI in both individual years and combined data. This suggests hoe weeding was very effective in controlling weeds. Several herbicide treatments showed promising results, particularly when combined with hoe weeding. These combinations often achieved weed control comparable to sole hoe weeding at 3 and 6 WAS. Among herbicides, a combination of Imazethapyr and Pendimethalin at 1.0 kg ha^{-1} each, or Metolachlor and Pendimethalin at 2.0 kg ha^{-1} each, were generally effective, especially when combined with hoe weeding, although they were at par with other treatments. This finding demonstrated the effectiveness of implementing additional hoe weeding at a later stage to manage late-emerging weeds and expand the range of herbicidal treatment as earlier reported by several scientists (Adeyemi *et al*., 2019; Omovbude *et al.,* 2020; Naeem *et al.,* 2022; and Shittu et al., 2022; Shittu and Lamarana, 2024).

Table 6. Weed covers score, Weed index and Weed control index of Cowpea as influenced by Weed control treatments during 2019 and 2020 rainy season

Treatment	Weed covers score			Weed index			Weed control index (%)		
	2019	2020	C	2019	2020	C	2019	2020	C
Weedy check	9.0a	8.00a	8.50a	53.57a	54.73a	54.15a	0.00h	0.00g	0.00i
Hoe weeding at 3 and 6 WAS[1]	1.67h	2.33cd	2.00h	0.00e	0.00g	0.00f	78.53a	78.53a	78.53a
Metolachlor at 2.0 kg a.i.ha^{-1}	6.33b	5.33b	5.83b	38.20b	39.20b	38.70b	46.50fg	47.67ef	47.08gh
Imazethapyr 3.0 kg a.i.ha^{-1}	5.67bc	5.00b	5.33bc	36.17b	36.53bc	36.35bc	50.73efg	50.73ef	50.73g
Pendimethalin 2.0 kg a.i.ha^{-1}	5.00cd	4.67b	4.83c	33.70b	34.30bc	34.00cd	58.50b-f	58.50b-e	58.50f
Pendimethalin 2.0 kg a.i.ha^{-1}	4.67d	4.67b	4.667cd	32.00b	30.60cd	30.47d	57.40def	57.40def	57.40f
Imazethapyr 1.0 + Pendimethalin 1.0 kg a.i.ha^{-1}	4.67cd	3.33c	4.00de	32.00b	31.63bc	31.82d	60.00b-e	60.00b-e	60.00def
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1}	4.33d	3.33c	3.83e	30.33b	30.60cd	30.47d	60.00b-e	60.00b-e	60.00def
Imazethapyr 1.0 + Pendimethalin 1.0 kg a.i.ha^{-1} + SHW at 6 WAS[2]	3.33e	2.67cd	3.00f	21.43cd	22.97def	22.20e	66.10a-d	66.10a-d	66.10b-e
Metolachlor 1.5 + Pendimethalin 1.5 kg a.i.ha^{-1} + SHW at 6 WAS	3.33ef	2.67cd	3.00fg	22.80c	23.27e	23.03e	66.50a-d	66.50a-d	66.50b-d
Metolachlor 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	2.67efg	2.000d	2.33fgh	22.73cd	23.17e	22.95e	72.47ab	72.47ab	72.47b
Pendimethalin 2.0 kg a.i.ha^{-1} + SHW at 6 WAS	2.33e-h	2.00d	2.17fh	22.70cd	23.07de	22.88e	72.17abc	72.17abc	72.17abc
P of F	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
SE±	0.2611	0.2706	0.2412	1.880	1.963	1.199	3.182	3.199	1.976

C: Combined; Means followed by the common letter (s) in a in column are not significantly different at 5% according to Student- Newman-Keuls Test (SNK). [1]WAS = weeks after sowing; [2]SHW= Supplementary hoe weeding

Conclusion

This study investigated the impact of different weed control strategies on cowpea growth, yield, and weed control. The results demonstrated that weed control significantly influenced crop performance. Findings further revealed that herbicidal treatments, combined with hoe weeding, effectively control weeds, improving crop growth and yield, enhancing plant height, leaf area, light interception, and seed production. Therefore, integrated weed management involves combining pre-emergence herbicides with post-emergence hoe weeding, selecting appropriate herbicides based on weed spectrum, crop tolerance, and environmental factors, and implementing cultural practices for optimal control and increases the productivity of cowpea in the study area.

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Effect of Some Packaging Materials on Seed Viability of *Arachis hypogaea* L (Groundnut)

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Abstract

This study investigates the effect of various packaging materia
ls on the seed viability of Groundnut (*Arachis hypogaea*), SAMNUT 24 variety. Conducted at the Department of Biological Science laboratory, Ibrahim Badamasi Babangida University, the experiment employed a complete randomized design with five packaging materials:namel; polythene bag, paper bag, cloth bag, aluminum foil, and jute bag. Each material contained 1 kg of seeds, stored for six months. Post-storage, a germination test was performed using 20 seeds from each packaging type, with parameters including germination percentage, germination index, germination rate index, and vigor index assessed after seven days. Results indicated that packaging materials significantly affected seed quality, with aluminum foil demonstrating the highest germination percentage (98.34%) and vigor index (3423.06), followed closely by polythene bags. In contrast, cloth bags yielded the lowest values for both germination percentage (67.45%) and vigor index (987.45). These findings align with existing literature suggesting that effective packaging is crucial for preserving seed viability by protecting against environmental factors. The study underscores the importance of selecting appropriate packaging materials to enhance seed quality and agricultural productivity, with aluminum foil and polythene bags as the most effective in groundnut seed storage.

Key Words: *germination index, storage, polythene , paper cloth , aluminum foil, jute bag*

Introduction

Groundnut (*Arachis hypogaea* L.) is a leguminous oil seed plant grown in semi-arid and sub-tropical regions across the globe (Hussainy et al., 2020). The peanut (*Arachis hypogaea*), also known as the groundnut is a legume crop grown mainly for its edible seeds. It is widely grown in the tropics and subtropics, important to both small and large commercial producers. It is classified as a grain legume and, due to its high oil content, an oil crop (Variath and Janila 2017). The world's annual production of shelled peanuts was 44 million tonnes in 2016, led by China, which made up 38% of the world's total production (Variath and Janila 2017)..

Kebede, (2021) reported that groundnut enhances soil fertility through nitrogen fixation, increasing crop productivity when integrated into crop rotation or cereal farming systems. The limited success of groundnut cultivation in African nations can be attributed to a combination of factors (Mwalongo, et al., 2020). These include unreliable rainfall, predominantly rain-fed farming practices, traditional small-scale farming with minimal mechanization, occurrences of pests and diseases, the use of low-yielding varieties, continued cultivation on suboptimal lands, insufficient adoption of modern agronomic techniques, lack of extension services and poor storage of Groundnut seeds which result to low germination percentage.

Several factors are responsible for declining groundnut yield in Sub-Saharan Africa (Abady et al., 2019). This includes declining soil fertility, pest, and disease incidence as well as germination failure as a result of poor-quality seeds. Enyiukwu et al. (2020) reported that germination failure in groundnuts occasioned by inappropriate storage environments and packaging materials. It is expedient to ascertain the most appropriate packaging material for the preservation of groundnut seed quality.

As a result of poor storage of Groundnut (*Arachis hypogaea* L), farmers have been faced with the problem of low germination percentage, which leads to low yield. Therefore, this study will aim to evaluate the effects of some packaging materials on seed viability of groundnut (*Arachis hypogaea* L) as this will ensure long term storage of the crop.

Materials And Method

Experimental Site

The experiment was conducted at the Laboratory of Department of Biological Science Faculty of Natural Sciences, Ibrahim Badamasi Babangida University main campus, Lapai, Niger State, Nigeria which lies between the latitude of 9.0674ON and longitude 6.5618OE.

Samples Collection

Groundnut *(Arachis hypogeae)* SAMNUT 24 variety was obtained from the Seed Center, Joseph SarwuanTarka University Makurdi, Benue State

Experimental Design

The experiment consisted of one variety of groundnut, (SAMNUT 24) and five (5) packaging materials (polythene bag, cloth bag, paper bag, Aluminium foil, paper bag and jute bag). One kilogram (1kg) of the groundnut variety was measured and kept in each of the packaging materials and stored for duration of 6 months at room temperature

Seed Viability Tests of the groundnut samples

Germination test

After storage, 20 seeds from each of the packaging materials were placed in a petri-dish with filter paper. A total of 25 petri-dishes were used. 5 petri-dishes representing each of the 5 packaging materials and were arranged in a complete randomized design (CRD) in ttriplicates. The seeds in each of the petri-dishes were watered daily and the following parameters shall be calculated:

- $G\% = \frac{\text{Total no.of seedlings emerged}}{\text{Total no.of seeds sown}}$ x 100 (Fakorade and Ojo, 1981)
- $GI = \frac{number\ of\ germinated\ seeds}{days\ of first\ count} + \cdots + \frac{\text{number of germinated seeds}}{days\ of\ final\ count}$ (AOSA, 1983)
- $GRI = \frac{\text{EI}}{\text{E\% (in decimal)}}$ (Fakorade and Ojo, 1981)

Seedling vigor index I, was calculated by multiplying the germination percentage with the mean shoot and root length after 7 days of germination.

Vigor index I = germination percentage × seedling shoot + root length in cm (Beedi et al., 2018).

Data Analysis

Data collected on all the parameters was subjected to analysis of variance (ANOVA) using the Minitab 2017 version and significant means will be separated using Fischer's Least Significant Difference (F.S.L.D) at 5% level of probability.

Results

Mean Squares from Analysis of Variance for Seed Quality of Groundnut

The mean squares from the analysis of variance for the physiological seed quality of groundnut is shown in Table 1. The table showed that packaging materials had a highly significant ($p \leq 0.01$) effect on germination percentage and germination index. On the other hand, packaging material was significant ($p \leq 0.05$) for germination rate index and vigor index.

Table 1. Mean Squares from Analysis of Variance for Seed Quality of Groundnut

SOV	DF	Germination %	Germination Index	Germination Rate Index	Vigor Index
Replication	2	234.23	12.01	651.80	11.56
Packaging Material	4	112.23**	131.92**	121.89*	123.90*
Error	4	36.34	23.46	67.10	38.12

Mean Effect of Packaging Materials on Seed Quality of Groundnut

The result of the mean effect of packaging materials on physiological seed quality of groundnuts is indicated in Table 2. The result of this table showed that seeds stored with aluminium foil recorded the highest germination percentage (98.34), although not significantly higher than those stored in polythene bag (95.97) but were significantly different from seeds stored in paper bag (76.34), cloth bag (67.45) and jute bag (79.52). Seeds stored in cloth bag recorded the lowest germination percentage. Similarly, the germination index was significantly highest in seeds stored in aluminium foil (34.45) but it was not statistically different from seeds stored in polythene bag (34.94). However, both were significantly different from the paper bag (23.78), jute bag (24.82), and cloth bag (25.52).

The lowest germination index was recorded by seeds stored in paper bag. A similar observation was recorded germination rate index where seeds stored in aluminium foil producing the highest germination rate index (401.02) and seeds stored in cloth bag producing the lowest germination rate index (267.98). The vigor index also was observed to follow a similar trend with aluminium foil and polythene bag producing significantly highest vigor index 3423.06 and 3211.90 respectively. Seeds stored in cloth bag were observed to produce the least vigor index (987.45).

Table 2. Mean Effect of Packaging Materials on Seed Quality of Groundnut

Packaging Material	Germination %	Germination Index	Germination Rate Index	Vigor Index
Polythene Bag	95.97	34.94	398.23	3211.90
Paper Bag	76.34	23.78	287.89	1000.40
Cloth Bag	67.45	25.52	267.98	987.45
Aluminum Foil	98.34	35.45	401.02	3423.06
Jute Bag	79.52	24.82	301.02	1343.22
FLSD (P<0.05)	2.12	4.56	3.67	5.12

Discussion

The results of study reveals the significant impact of packaging materials on key seed quality parameters, including germination percentage, germination index, germination rate index, and vigor index. This underscores the critical role of packaging choices in influencing the overall quality of groundnut seeds. This falls in agreement with (Tiwari *et al*., 2022; Dadlani et al., 2023) who also maintained that adequate packaging can additionally safeguard the seeds against environmental factors (temperature and relative humidity) that cause seed deterioration, thereby preserving the integrity of their quality while in storage. Notably, different packaging materials exert varying levels of influence on these parameters, emphasizing the importance of making informed decisions regarding packaging materials to optimize seed quality.

Specifically, the study demonstrates that seeds stored in aluminium foil and polythene bags exhibit the highest germination percentages, which are essential for successful crop establishment. Conversely, seeds stored in paper bags, cloth bags, and jute bags show significantly lower germination percentages. Similarly, Haque, (2014) reported that polythene bags surpassed other storage materials excluding aluminium foil, in terms of achieving superior outcomes regarding germination rates, field emergence, and vigor index. This could be attributed to the fact that polythene prevents the influence of the seed and its external environment thereby preserving its quality.

Furthermore, the vigor index, a comprehensive measure of seed quality, indicates that aluminium foil and polythene bags excel in maintaining seed vigor, while cloth bags yield the lowest vigor index. This suggests that seeds stored in aluminium foil and polythene bags are more likely to produce robust and healthy plants, reinforcing the importance of packaging materials in achieving optimal seed quality. In support of this finding, Affognon et al., (2017) reported that aluminium foil as one of the best packaging materials for viable and vigorous seeds. Similarly, Mutungi et al., (2019). Also agrees with this findings.

These results have practical implications for agricultural practices and seed storage. Farmers and seed producers can use this information to make informed decisions about the choice of packaging materials for groundnut seeds. For optimal seed quality and crop performance, aluminium foil and polythene bags are more effective options compared to paper bags, cloth bags, or jute bags.

Conclusion

The research reveals that the seed viability of groundnuts, indicated that packaging materials have a significant role as far as the seed quality of groundnuts is concerned. Aluminium foil produced the highest seed quality in terms of generation percentage, germination index, germination rate index and vigor index. On the other hand, cloth bag gave the lowest seed quality.

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Green Synthesis of ZnO, CuO and ZnO-CuO Nanoparticles from Nigella sativa L. Extract and Effect of Nanoseed priming on Chickpea under Salinity Stress

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Abstract

Nigella sativa is a medicinal plant commonly referred to as "black cumin" and belongs to the family Ranunculaceae. Nanotechnology, a field that operates at the nanoscale, has numerous practical applications. Due to the unique properties of nanoparticles—including their large surface area, high reactivity, aggregation tendencies, penetration capability, small size, and distinct structure—nanotechnology has enabled a wide range of applications in agriculture. Biosynthesis offers a safe and environmentally friendly method for producing non-toxic, biodegradable nanoparticles (NPs). The objective of the present study was to synthesize ZnO, ZnO-CuO, and CuO NPs from *N. sativa* and to evaluate the impact of seed priming with these nanoparticles on the overall morphology, germination, and growth of chickpea (*Cicer arietinum*) under salt stress conditions. The synthesized NPs were characterized FTIR, XRD, DLS, SEM, and UV-Vis. For nanoseed priming, chickpea seeds were soaked in ZnO, CuO, and ZnO-CuO nanocomposite solutions at varying concentrations (100 ppm, 250 ppm, 500 ppm). The effects of ZnO, CuO, and ZnO-CuO NPs on germination, growth, and biochemical parameters of chickpea under salt stress were analyzed. Salt stress was applied in two phases. Various physiological and biochemical parameters were assessed, including catalase and peroxidase activities, hydrogen peroxide levels, seedling root and shoot lengths, fresh and dry weights, number of leaves, and lateral root development. Chickpea exhibited tolerance to salinity during the flowering stage, contributing to its stability and enhanced productivity. Following data collection, raw data were analyzed using the statistical software STAR. Nanoseed priming showed potential benefits in improving germination rates, enhancing seedling growth, and increasing stress tolerance, making it a promising approach for sustainable agriculture. The findings of this study suggest that ZnO, CuO, and ZnO-CuO seed priming can enhance chickpea growth under saline conditions. Improved seedling performance was associated with increased shoot and root lengths, fresh and dry biomass, and antioxidant enzyme activity, which collectively mitigated salt stress effects through nano-priming.

Key Words:

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Transformation of Common Dates of Low Market Value into Crystallized Sugar by Freeze-Drying Process

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Abstract

The common dates can serve as an effective substitute for commercial white sugar, whether it is in the form of icing or crystallized sugar, and their utilization could represent a significant enhancement in terms of socio-economic benefits. The process of producing sugar from these dates begins with the cultivation of low-value date crops. The dates undergo a thorough washing process with water, effectively separating them from any grass, dirt, and other unwanted materials. Once cleaned, the dates are cut open to remove their pits. The extraction of sweet juice from the dates is achieved through a diffusion method. This technique facilitates the transfer of sugar from the date pulp into the water. Adding dates and distilled water in ratio (1/5) in a large flask to hot plate at temperature 65°C and turn slowly for 30 to 60 minutes. After this extraction phase, the sweet juice is filtered using a vacuum pump. The resulting juice contains not only the sugars derived from the dates but also various impurities that must be removed, including mineral salts and organic compounds. To achieve this purification, the filtration process employs lime milk treatment. This combination leads to the formation of insoluble salts and sediments that help stabilize and eliminate the impurities present in the juice. After this treatment, the mixture is passed through filters designed to capture the impurities while allowing the pure sweet juice to flow through. At this stage of processing, the filtered juice is composed of approximately 20% sugar and 80% water.
Using a rotavape, the juice is concentrated at 40°C until it becomes a syrup containing 65% to 70% sucrose, the syrup is then frozen, then sublimated, and finally desorption (lyophilization) by freeze-drying transforms it into crystallized sugar, ready for various applications.

Key Words: *Common Dates, sugar, extraction, filtration, clarification, freeze-drying*

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Honeybee Preferences for Pollen Substitute Diets: A Climatic Perspective

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Abstract

Honey bees (*Apis mellifera* L.) are the best known and most effective pollinating insects. Not enough information is available on the nutrition of these insects. Various products are used as protein sources for the diet of bees, and these products are usually given to the colony in the form of cake. There is little research on dry protein substitutes used for feeding bees outside the colony. In this study, the preference of bees for different dry protein substitutes was investigated in continental and subtropical climates. The results show that the seven different formulations are most preferred by the bees. In the subtropical climate, the bees showed no interest in these feeds, while in the continental climate they showed considerable interest. In addition, bees visited dark-colored baits more. In addition, baits close to the colonies were preferred more.

Key Words: *Apis, Dry, Feeding, Foraging, Substitute*

Introduction

Pollinators are an important species for the sustainability of flowering plants. Among these species, honeybees (*Apis mellifera* L.) are the most widespread and economically important species for humans (Güneşdoğdu et al., 2023). This species needs nutrients to survive and reproduce. These nutrients are carbohydrates, amino acids, lipids, vitamins, minerals, and water (Huang, 2012). Bees meet their carbohydrate requirements from nectar and honey. When these sources are scarce in nature, beekeepers add sugar syrup. Pollen provides the bees with amino acids, vitamins, minerals, and fats. When pollen is not available in nature, beekeepers use pollen diets or pollen substitutes. There are only a limited number of protein feeds for bees worldwide. These products are not yet sold in most countries (Güneşdoğdu et al., 2024).

The development of pollen substitutes for honeybees has long been of interest to the beekeeping industry. The development of such products makes it possible to feed the bees with protein feed and increase their productivity. Especially from fall to early spring, when there are no natural pollen sources in the environment, these substitutes induce the start of brood production in the colonies and the production of healthy offspring (Zahra and Talal, 2008). For honey production, it is important to start the nectar flow with strong colonies.

It is important to provide protein feed, promote the strengthening of bee colonies, maximize pollination, and protect them from pesticides, parasites, and diseases. Efficient forage production for animals, including insects, depends on palatability, health, and cost (Wilson et al., 2005). However, even a balanced diet that contains all nutrients is only important if it is consumed by the animal. It depends on whether it is consumed by the animals (Forbes, 1995). For bees, the fat and protein content in pollen is important for attractiveness (Ghosh et al., 2020).

Supplying powdered pollen substitutes to honey bee colonies is a simple method and requires minimal time and labor if weather conditions allow bees to leave the hives in search of food (Saffari et al., 2010).

Materials and Methods

Study Locations and Colony Information

This study was conducted in Muş/Turkey (38°46'19"N 41°25'47"E) and Tarsus/Mersin/Turkey (36°57'10"N 34°51'20"E) in the fall and in Kulp/Diyarbakır/Turkey (38°28'30"N 41°02'42"E) and Tarsus/Mersin/Turkey (36°57'10"N 34°51'20"E) in February and March (Figure 1). The elevation of these locations was 1290 mt, 110 mt, and 802 mt above sea level, respectively. There was a total of 105 honey bee colonies in the apiary. The colonies consisted of 3-8 bee covered frames.



Figure 1. Locations where the study was conducted in Turkey.

Raw materials and formulations

The raw materials listed in Table 1 were used to produce the dry pollen substitutes. The raw materials used are in powder or flour form. The quantities listed in Table 2 were used to produce the feeds. Many feed types were formulated, but the seven feed types that were most popular with the bees were indicated.

Table 1. Products used and their nutritional value (g/100g)

Raw Materials	Calories (kcal)	Protein	Carbohydrate	Fat
Ground Rice Flour	365.00	6.00	80.00	1.40
Corn Flour	167.00	5.50	73.00	3.50
Breadcrumbs Flour	395.00	13.50	72.00	5.30
Wheat Flour	200.00	10.50	76.00	1.00
Einkorn Wheat Flour	366.00	13.50	66.00	1.50
Soybean Flour	347.00	38.00	32.00	20.00
Corn Gluten Powder	385.00	60.00	13.00	2.00
Rye Flour	227.00	6.50	71.00	1.50
Chickpea Flour	387.00	23.00	63.00	5.00
Wheat Bran	60.00	14.80	17.50	4.00
Skim Milk Powder	500.00	35.5	100.00	1.00
Dry Yeast Powder	353.00	39.00	22.00	7.50
Cinnamon Powder	272.00	4.00	56.00	3.00
Turmeric Powder	354.00	8.00	65.00	10.00
Ginder Powder	79.00	1.80	18.00	1.00
Rock Salt	2.00	0.40	0.00	0.00
Wheat Starch	177.00	0.17	87.00	0.14

Results and Discussion

Numerous diet compositions were tested. Table 2 shows seven diet compositions that were of great interest to the bees. The results are from three different locations. In Mersin, the bees showed no interest in any forage composition. This could be due to the year-round agricultural activity and natural pollen sources in this region. At the other two sites, the bees were interested in a range of forage compositions (Figure 2). This is thought to be due to the continental climate in these regions and the lack of natural pollen sources at the beginning of the fall season. When bees are offered such diets, it is not known which ones they will choose. Saffari et al. (2010) reported that among three different commercial dry pollen substitutes (Feedbee®, Bee-Pro®, and TLS Bee Feed), Feedbee® was the most attractive. The protein, fat and carbohydrate contents of this product were 36.4%, 3.9%, and 51.8%, respectively. Gregory (2006) and De Jong et al. (2009) reported that these diets increased the protein level in the hemolymph. Furthermore, Gregory (2006) reported that pollen was the most effective in terms of lifespan and colony strength, followed by Feedbee®, Bee-Pro® products.

Recommendations for the use of dry diets;

- The feeding sites should be in the immediate vicinity of the colonies,
- It should be in a shady place without direct sunlight,
- It must be protected from the wind,
- Yellow and darker colored flours should be preferred,
- White flour is rarely preferred,
- It should have good moisture and oil content,
- Pollen sources must be scarce in nature,
- The bees need time to get used to it, there should be no rush.



Table 2. Diets and their proportions (g/100g)

Raw Materials	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7
Ground Rice Flour	20	-	-	-	-	-	15
Corn Flour	20	-	-	-	-	10	-
Breadcrumbs Flour	20	-	-	-	-	10	-
Wheat Flour	-	20	-	-	-	-	15
Einkorn Wheat Flour	-	20	-	-	-	-	15
Soybean Flour	-	20	-	60	-	10	-
Corn Gluten Powder	-	-	20	-	60	10	-
Rye Flour	-	-	20	-	-	10	-
Chickpea Flour	-	-	20	-	-	10	-
Wheat Bran	15	15	15	15	15	10	-
Skim Milk Powder	10	10	10	10	10	-	15
Dry Yeast Powder	3	3	3	3	3	-	15
Cinnamon Powder	2	2	2	2	2	-	15
Turmeric Powder	2	2	2	2	2	10	-
Ginder Powder	2	2	2	2	2	10	-
Rock Salt	1	1	1	1	1		-
Wheat Starch	5	5	5	5	5	10	10
Total	100	100	100	100	100	100	100



Figure 2. Different diets and forager bees' density

Conclusion

Honey bees have an important place in people's lives, even if many people are not aware of this. Measures must be taken to reduce the negative impact on these insects. We need to control pests and ensure the quality of food for bees. There is very little research on substitutes for dry pollen. There is a need for numerous studies like our study.

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Possibilities of Using Microalgea Varieties in Beekeeping Research

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Abstract

In medicine, microalgae are used to produce food supplements and medicines. In particular, algae such as spirulina and chlorella with their high content of proteins, vitamins, minerals and omega-3 fatty acids have positive effects on health. In addition, some types of microalgae have antimicrobial and antiviral properties and are being studied in the treatment of cancer and cardiovascular diseases. In animal husbandry, microalgae are used as a feed additive to improve animal nutrition. Microalgae can accelerate the growth of animals, strengthen their immune system and reduce environmental pollution. In particular, algae used in feed for ruminants can reduce methane emissions. In beekeeping, microalgae are used as food supplements for bees. Food supplements with microalgae can strengthen the bees' immune system and increase their survival rate in winter. In addition, microalgae can promote the production of compounds that increase propolis production. In summary, microalgae offer important health, productivity and environmental benefits in areas such as medicine, animal husbandry and beekeeping. Research in this field continues to provide solutions to support the sustainable and efficient use of microalgae.

Key Words: *Microalgea, Eco-frendly beekeeping, Study, Bee health, Sustainable*

Introduction

Algae comprise about 25,000-50,000 species of different sizes, shapes, pigments and functional compounds (Guiry, 2018). They are generally divided into prokaryotic unicellular cyanobacterial microalgae (blue-green algae) and eukaryotic unicellularand multicellular algae (green algae, red algae and brown algae) (Yaakob et al., 2014; Pereira, 2021; Ullmann and Grimm, 2021). Algae species have been known for centuries and are used in almost all areas of industry. Especially in the countries of the Far East and South Asia, algae species, which are widely used as food, in the medical, pharmaceutical and cosmetic industries and in the production of fertilizers in agriculture, are not only collected in their natural habitats, but also cultivated in the oceans and grown like plants on land (Atay, 1984). They are classified according to the ecosystem in which they occur, their size, their pigments and whether they are prokaryotic or eukaryotic. Algae that do not have true roots, stems and leaves are divided into microalgae and macroalgae according to their size.

Macroalgae are plant organisms that are between 1-2 cm and 40-50 m in size, depending on the species, and provide aquatic organisms with food, protection and reproduction. Macroalgae species have been used in the past as food, fertilizer, animal feed, dye, thickener, soap, glass raw material, gelling agent and to produce biofuels (Jensen, 1966). Microalgae are heterogeneous microorganisms that do not belong to a specific taxonomic group. They can be unicellular, colonial or filamentous. From an ecological point of view, they form a community of unicellular algae belonging to different large groups. Microalgae are widely distributed in freshwater, brackish, and marine ecosystems, although certain species are also capable of thriving in terrestrial environments such as rocks and soils. These microorganisms are the focus of research in botany, phycology, and microbiology. Cyanobacteria, which possess a prokaryotic structure, are not only studied within the fields of botany and phycology but also extensively researched in microbiology. From an ecological perspective, cyanobacteria, unicellular green and red algae, euglenoids (*Euglenophyta*), chrysophytes (*Chrysophyta*), and dinoflagellates (*Dinoflagellata*) collectively constitute the group of microalgae.

As photosynthetic organisms, microalgae play a crucial role in sustaining life on Earth. They contribute significantly to atmospheric oxygen production while simultaneously utilizing carbon dioxide for photoautotrophic growth. Their exceptional biodiversity enables them to inhabit diverse regions across the biosphere. Furthermore, microalgae exhibit remarkable resilience to environmental stressors, allowing them to withstand conditions such as temperature fluctuations, drought, salinity, photo-oxidative stress, anaerobic environments, osmotic pressure, and UV radiation (Minhas et al., 2016).

Numerous algal species have the ability to synthesize bioactive compounds with allelopathic properties. Allelopathy refers to a biological phenomenon in which an organism releases specific biochemical substances that influence the germination, growth, survival, and reproduction of other organisms within its environment. These compounds, classified as allelochemicals, belong to the category of secondary metabolites and can exert either beneficial (positive allelopathy) or detrimental (negative allelopathy) effects on target organisms and ecosystems. The allelopathic potential of microalgae has been explored as a biological strategy for controlling algal blooms and mitigating microbial contamination caused by bacteria, fungi, and protozoa.

Microalgae are also recognized for their ability to produce a wide range of biologically active compounds (BACs) with applications in biotechnology and clinical research. The emergence of antibiotic resistance among bacteria and other microorganisms poses a significant threat to both human and animal health. In this context, microalgae are considered promising candidates for the discovery of novel antibacterial agents that may circumvent resistance mechanisms. Notably, large-scale cultivation of microalgae in photobioreactors can be conducted under controlled conditions, facilitating the production of high or even ultra-high-density cultures (Richmond, 2004; Gordon and Polle, 2007; Sun et al., 2019; Wang et al., 2019; Jin et al., 2020).
This mini-review presents findings related to the utilization of selected microalgae species in various ecosystems and explores their potential applications in beekeeping. Additionally, the discussion addresses their contributions to sustainability and environmental conservation.

Sustainability and environmental benefits: Use of microalgae in beekeeping and impact on the environment
In recent years, microalgae have attracted attention as an important alternative in agriculture and animal husbandry due to their rapid biomass production potential, low environmental footprint and sustainable production methods. Considering the limitations and environmental impact of conventional feeds, microalgae represent a nutritionally and environmentally beneficial option for beekeeping.

Ecological advantages of microalgae production
Microalgae can produce large amounts of biomass through photosynthesis and contribute to the fight against climate change by absorbing carbon dioxide (CO_2) from the atmosphere during this process (Chisti, 2007). In contrast to traditional agricultural practices, the cultivation of microalgae does not cause any expansion of agricultural land or the loss of habitat (Wijffels et al., 2010). In addition, the use of saltwater or recycled wastewater instead of freshwater for microalgae cultivation enables efficient use of water resources (Pittman et al., 2011). This characteristic makes microalgae an attractive alternative in areas with water scarcity.

Sustainability of the use of microalgae in bee nutrition
Sugar syrup and pollen substitute commonly used in beekeeping may not be sufficient in terms of nutritional value and environmental sustainability. Microalgae can contribute to bee nutrition with their high content of proteins, essential amino acids, omega-3 fatty acids and antioxidants (Becker, 2007). These nutrients can boost bee immunity, improve colony health and reduce losses. In addition, the use of microalgae-based feeds can reduce the environmental impact of beekeeping. The production of sugar syrup usually requires large agricultural areas and large amounts of water. The use of microalgae-based feeds offers an environmentally friendly approach by ensuring a more efficient consumption of these resources (Barsanti and Gualtieri, 2014).

Prospects
For microalgae to be widely used in beekeeping, it is of great importance to reduce production costs and develop scalable production techniques. In addition, the long-term effects of microalgae-based feed on bees should be studied in more detail. Scientific studies in this area can accelerate the acceptance of microalgae as a sustainable option for beekeeping. Therefore, microalgae have significant potential as a sustainable feed source that minimizes environmental impact and improves bee health. Research on this topic can make a valuable contribution to both beekeeping and ecosystem conservation.

Effects and use as food
Although honeybee colony losses are thought to be due to a combination of stress factors, research shows that malnutrition is one of the main causes of these losses. Commercial beekeepers are increasingly turning to artificial pollen substitutes to support their colonies in times of food shortages and to increase bee populations prior to pollination. Nevertheless, these artificial diets are known to lack essential macronutrients, including proteins, lipids, prebiotic fibers, as well as vital micronutrients such as vitamins, minerals, and antioxidants. Consequently, enhancing the nutritional profile of pollen substitutes has become a crucial aspect of contemporary beekeeping practices. Microalgae offer considerable potential for plant nutrition as their biochemical composition is similar to that of natural pollen. Although there are few studies on honeybees, microalgae have been extensively studied in insect nutrition (Qiu et al., 2019), aquaculture (Guedes et al., 2015), animal husbandry (Madeira et al., 2017) and human nutrition (Caporgno & Mathys, 2018). The nutritional content of microalgae has been extensively characterized, and it has been shown that they can be evaluated both as a sole source of protein and as a feed additive for various organisms (Guedes et al., 2015; Madeira et al., 2017). Microalgae are rich sources of carotenoid pigments, particularly lutein, zeaxanthin, and astaxanthin, which have been shown to improve survival rates in various organisms when incorporated into their diet (Merchie et al., 1998; Babin et al., 2010). The most promising microalgae species in terms of beekeeping are Arthrospira and Chlorella. Arthrospira (known as Spirulina) consists of 60-70% of its dry weight in protein and is a highly bioavailable protein source. About half of the proteins contain essential amino acids (EAA) (Soni et al., 2017). Similarly, chlorella species have a protein

content of 50-60% and offer a complete EAA profile (Kotrbáček et al., 2015). Arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine are among the essential amino acids required by honeybees, and these amino acids must be obtained from the diet. When worker bees consume pollen, these amino acids are incorporated into the vitellogenin lipoprotein in the fat body and form the precursor of the proteins of the hypopharyngeal glands that are secreted to feed the larvae (Crailsheim, 1990). A recent study has shown that Chlorella sorokiniana has positive effects on the growth and individual nutritional physiology of honey bee colonies. According to the results of the study, bees fed with this microalga showed an increase in fat body protein content, vitellogenin mRNA levels and hypopharyngeal gland size. These results suggest that chlorella is promising as a pollen substitute or dietary supplement (Jehlík et al., 2019).

In another study, a pollen substitute formulation containing Arthrospira was found to increase the performance of bee colonies compared to unfed control colonies (Kumar et al., 2013). However, the exact effects of Arthrospira on the health of individual bees and colony dynamics are not yet fully known. Two essential polyunsaturated fatty acids (PUFAs) that are important for honeybees are linoleic acid and α-linolenic acid (Arien et al., 2015). Studies have shown that dietary PUFA content is related to vitellogenin expression in the fat body (Wegener et al., 2018). 10-20% of the dry weight of Chlorella sorokiniana consists of lipids and studies have shown that this microalga increases fat storage in bees (Jehlík et al., 2019). However, species such as Botryococcus (25-75%), Nanochloropsis (31-68%) and Schizochytrium (50-77%) are known to have a much higher lipid content (Demirbaş and Demirbaş, 2011). Microalgae also contain valuable sources of vitamins such as tocopherols, ascorbic acid and B vitamins, as well as essential minerals such as sodium, potassium, calcium and magnesium (Fábregas and Herrero, 1990). Studies have shown that in worker bees fed with Chlorella vulgaris and Arthrospira platensis, growth rates increase, antioxidant defenses are strengthened, and the expression of heat shock proteins increases (Ricigliano et al., 2022). A significant increase in vitellogenin mRNA expression levels was observed in bees fed spirulina (Ricigliano et al., 2021). In addition, hypopharyngeal gland development, an increase in amino acid content and an increase in vitellogenin mRNA levels were observed in bees whose diet was supplemented with 0.5-10% Chlorella sorokiniana (Jang et al., 2022). In another study, it was reported that bee colonies fed with feed containing 25% spirulina produced more brood compared to the control group (McMenamin et al., 2023). Similarly, the positive effects of feeds containing chlorella (2%) on worker bees and colony health are highlighted (Jang et al., 2023). In addition, spirulina (2 g) was found to have positive effects on vitellogenin expression, abdominal lipid ratio and hypopharyngeal gland development (Güneşdoğdu et al., 2024). Experimental hives fed with Spirulina platensis, Scenedesmus quadricauda, Scenedesmus apiculatus, and Oocystis borgei Snow showed a 2.7% increase in hygienic behavior compared to control hives fed with honey and powdered sugar (Toderas et al., 2017). These results suggest that microalgae can be considered an important food source for honeybees and have the potential to be used as a pollen substitute or food supplement.

Table 1. Nutritional Content and Potential Benefits of Microalgae for Honey Bees

Microalgae	Nutritional Content and Benefits	References
Spirulina platensis	60-70% protein, high bioavailability amino acids, Vitamin and mineral source, Increases bee development and nutritional value, Increases vitellogenin level.	Soni et al., (2017) Becker (2007) Kumar et al., (2013) Güneşdoğdu et al., (2024)
Chlorella spp.	50-60% protein, full essential amino acid profile, High chlorophyll and antioxidant content.	Kotrbáček et al., (2015) Fábregas ve Herrero (1990)
Chlorella sorokiniana	Increases vitellogenin level.	Jehlík et al., (2019)
Chlorella vulgaris	It strengthens bee immunity and increases vitellogenin level.	Ricigliano et al., (2022)
Dunaliella salina	It is rich in beta-carotene.	Caporgno and Mathys (2018)

Antibacterial effect

The antimicrobial properties of microalgae have been associated with various bioactive compounds spanning multiple chemical classes, such as indoles, terpenes, acetogenins, phenols, fatty acids, and volatile halogenated hydrocarbons (Mayer and Hamann, 2005; Cardozo et al., 2007). For instance, the antimicrobial potential of supercritical extracts derived from the microalga *Chaetoceros muelleri* has been attributed to its lipid composition (Mendiola et al., 2007). Similarly, the antimicrobial effects observed in different pressurized extracts of *Dunaliella salina* are not solely linked to fatty acids but are also influenced by other bioactive compounds, including α- and β-ionone, β-cyclocitral, neophytadiene, and phytol (Herrero et al., 2006). As antibacterial agents, microalgae can prevent the occurrence of bacterial diseases. It has been shown that algae-derived long-chain polyunsaturated fatty acids (LC-PUFAs) and algal sterols, such as eicosapentaenoic acid (EPA), have antibacterial properties and can be effective against both Gram-positive and Gram-negative bacteria (Benkendorff et al., 2005; Desbois et al., 2009). A microalgae homogenate obtained from Tetraselmis suecica showed good in vitro antibacterial activity

against various Vibrio species, including important shrimp pathogens such as Vibrio alginolyticus, Vibrio anguillarum, Vibrio parahaemolyticus and Vibrio vulnificus (Austin and Day, 1990). Honeybees infected with *Nosema ceranae* and provided with extracts from *Porphyridium marinum* and *Porphyridium purpureum* exhibited a reduced parasite load compared to the control group. Experimental bees experienced up to a 30% decrease in *Nosema* infection levels relative to untreated controls, and the parasite burden was approximately half that observed in fumagillin-treated individuals (Roussel et al., 2015). Additionally, extracts of *Chlorella sorokiniana* demonstrated antimicrobial activity against plate cultures of *Paenibacillus larvae* (Vránová, 2017), while similar inhibitory effects were noted when *Chlorella vulgaris* extracts were applied to spores and vegetative cultures of *Paenibacillus larvae* (Dostálková et al., 2021).

Microalgae cultures of Chlorella minutissima, Tetraselmis chui, Nannochloropsis species, Arthrospira platensis, and Isochrysis species have been shown to inhibit the growth of bacteria (Vibrio parahaemolyticus, V. anguillarum, V. splendidus, V. scophthalmi, V. alginolyticus, and V. lentus) (Kokou et al., 2012). The first antibacterial compound isolated in history (chlorellin) is believed to have been obtained from the microalgae Chlorella, which showed inhibitory activity against Gram-positive and Gram-negative bacteria (Pratt et al., 1944).

Some microalgae species exhibit antimicrobial activity via various mechanisms. For instance, *Fischerella ambigua*, a cyanobacterium isolated from a soil sample, produces parsiguine, a bioactive compound with antibacterial and antifungal properties (Ghasemi et al., 2004). Parsiguine exhibits antimicrobial activity against *Staphylococcus epidermidis* PTCC 1114 and *Candida krusei* ATCC 44507. Additionally, the marine diatom *Phaeodactylum tricornutum* has been found to contain antibacterial compounds effective against various bacterial species (Desbois et al., 2009). The primary bioactive molecule identified in this microalga is eicosapentaenoic acid (EPA), which has demonstrated potent activity against multidrug-resistant *Staphylococcus aureus* (MRSA) strains 16a and 252, along with other *S. aureus* strains, *Staphylococcus epidermidis*, *Bacillus weihenstephanensis*, and *Bacillus cereus*. Furthermore, EPA has been reported to be effective against *Vibrio (Listonella) anguillarum*, a pathogen responsible for hemorrhagic septicemia in fish, as well as *Micrococcus luteus*, *Photobacterium* species, and *Planococcus citreus*. Notably, eicosapentaenoic acid has also been described as toxic to herbivorous organisms (Jüttner, 2001). Another bioactive compound isolated from *P. tricornutum*, hexadecatrienoic acid, has shown antibacterial effects against *S. aureus* (Amaro et al., 2011). On the other hand, ethanol extracts from the red stage of Haematococcus pluvialis were found to have antimicrobial activity against Escherichia coli and S. aureus. This effect is most likely due to the presence of the short-chain fatty acids butanoic acid and methyl lactic acid (Santoyo et al., 2009). Polyunsaturated aldehydes are of particular importance among the bioactive compounds of algal origin. These compounds are synthesized by diatoms and have been found in species such as Skeletonema marinoi (formerly Skeletonema costatum) (Vidoudez et al., 2008; Sarno et al., 2005), Pseudonitzschia delicatissima and Thalassiosira rotula (Miralto et al., 1999). Decadienal, one of the most important compounds in this group, shows strong antibacterial activity against important human pathogens such as methicillin-resistant strains of Staphylococcus aureus (MRSA) and Haemophilus influenzae as well as bacteria such as Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus and Staphylococcus epidermidis. It is thought that decadienal is probably derived from arachidonic acid. This compound has also been reported to inhibit the growth of various Gram-negative bacteria, including *Aeromonas hydrophila*, *Vibrio anguillarum*, *Alteromonas haloplanktis*, *Photobacterium phosphoreum*, and *Psychrobacter immobilis*, as well as Gram-positive species such as *Planococcus citreus* and *Micrococcus luteus* (Smith et al., 2010). Furthermore, extracellular metabolites secreted by *Skeletonema costatum* during its mid-growth phase have demonstrated antibacterial activity against *Listeria monocytogenes* (Terekhova et al., 2009). Organic extracts from *S. costatum* have also exhibited inhibitory effects on several *Vibrio* species (Naviner et al., 1999), specifically suppressing the growth of *Vibrio mytili* T, *Vibrio* sp. S322 (a pathogen affecting Japanese oyster larvae), *Vibrio* sp. VRP (a pathogen of mussel larvae), and *Vibrio anguillarum*.

Additionally, strains of *Chroococcus dispersus*, *Chlorella vulgaris*, and *Chlamydomonas reinhardtii* have shown considerable antibacterial effects against *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Bacillus subtilis*, *Escherichia coli*, and *Salmonella typhi* (Ghasemi et al., 2007). In the same study, *C. dispersus* strains were also found to inhibit the growth of *Pseudomonas aeruginosa*. Moreover, organic extracts obtained from *Euglena viridis* have demonstrated inhibitory effects on a range of bacterial species, including *Pseudomonas aeruginosa*, *Pseudomonas putida*, *Pseudomonas fluorescens*, *Aeromonas hydrophila*, *Edwardsiella tarda*, *Vibrio alginolyticus*, *Vibrio anguillarum*, *Vibrio fluvialis*, *Vibrio parahaemolyticus*, *Vibrio harveyi*, and *Escherichia coli* (Das et al., 2005).

Antiviral effect

Several viral diseases have emerged or re-emerged in recent years. Although there are some antiviral drugs specifically designed to combat these diseases, the constant emergence of drug-resistant mutations in viruses is a major problem. Therefore, microalgae are of great interest as potential sources of antiviral compounds (Borowitzka, 1995). According to Amaro et al. (2011), the viral infection process is divided into three phases: Initial phase: adsorption of the virus to the host cell and invasion of the cell; Mid-phase: the phase in which the

cell is forced to synthesize numerous copies of the virus; Final phase: the maturation of the new virus particles and their release from the cell. The effect of the antiviral drug acyclovir on the herpes simplex virus (HSV), for example, is observed in mid-phase of the viral infection (Elion et al., 1977). In contrast, antiviral factors derived from Dunaliella species neutralize the function of the virus in initial phase (Ohta et al., 1998). *Dunaliella primolecta* extract was found to have the highest antiviral activity against *HSV-1*. Three of these antiviral compounds were purified by chromatographic methods and NMR and MS analyzes showed that these compounds are phophorbide-like structures.

Sulfated polysaccharides from the cell wall of the red microalgae Porphyridium sp. have shown strong antiviral activity against the herpes simplex virus type 1 and 2 (HSV-1, HSV-2) and the varicella zoster virus (VZV) (Huleihel et al., 2001). These sulfated polysaccharides also inhibit the replication of two economically important viruses, viral hemorrhagic septicemia virus of salmonids (VHSV) and African swine fever virus (ASFV) (Fabregas et al., 1999). On the other hand, *allophycocyanin* extracted from *Spirulina platensis* has been observed to mitigate the cytopathic effects in cells infected with *enterovirus 71*. This viral infection poses a significant health risk, particularly in children, as it is associated with high morbidity and mortality rates. The discovery of the antiviral activity of *allophycocyanin* represents a noteworthy advancement in this field. Its mechanism of action has been linked to delaying viral RNA synthesis within infected cells while simultaneously reducing apoptosis in *enterovirus 71*-infected rhabdomyosarcoma cells (Shih et al., 2003).

Several polysaccharides derived from marine algae have also demonstrated substantial antiviral properties (Ahmadi et al., 2015). Among these is *naviculan*, a sulfated polysaccharide isolated from the diatom *Navicula directa* (Lee et al., 2006). Research findings indicate that *naviculan* exhibits strong antiviral effects against *HSV-1* and *HSV-2* (IC_{50}: 7–14 µg/mL) and plays a crucial role in inhibiting the early replication stages of the influenza virus. Notably, *naviculan* has also shown inhibitory activity against *HIV* by interfering with viral attachment and penetration processes. Additionally, it has been reported to prevent the fusion of *CD4*-expressing cells with *HeLa* cells expressing the *HIV* glycoprotein gp160.

Moreover, *p-KG03*, a sulfated exopolysaccharide extracted from *Gyrodinium impudicum*, has displayed significant antiviral activity against *encephalomyocarditis virus (EMCV)* in vitro (EC_{50} = 26.9 µg/mL) (Yim et al., 2004). Similarly, *Cochlodinium polykrikoides* produces polysaccharides (A1 and A2) capable of inhibiting the cytopathic effects of *influenza virus types A and B*, *respiratory syncytial virus types A and B*, and *HIV-1* (Hasui et al., 1995). In another study, *calcium spirulan* extracted from *Arthrospira platensis* demonstrated selective inhibition against multiple viruses, including *HSV-1* (in *HeLa* cells), *HCMV* (in *HEL* cells), *influenza A* (in *MDCK* cells), *Coxsackie virus* (in *Vero* cells), *measles* (in *Vero* cells), *HIV-1* (in *MT-4* cells), *poliovirus* (in *Vero* cells), and *mumps virus* (in *Vero* cells) (Hayashi et al., 1996).

Table 2. Antibacterial Effects of Microalgae on Various Bacteria

Microalgae	Bacteria It Affects	References
Chlorella minutissima	*Vibrio parahaemolyticus, V. anguillarum, V. splendidus, V. scophthalmi, V. alginolyticus*, and *V. lentus*	Kokou et al., (2012)
Tetraselmis chui		
Nannochloropsis spp.		
Arthrospira platensis		
Isochrysis spp.		
Chlorella spp.	*Gram-positive and Gram-negative bacteria*	Pratt et al., (1944)
Fischerella ambigua	*Staphylococcus epidermidis* and *Candida krusei*	Ghasemi et al., (2004)
Phaeodactylum tricornutum	*Staphylococcus aureus (MRSA), S. epidermidis, Bacillus cereus, Vibrio anguillarum, Micrococcus luteus*, and *Photobacterium* spp.	Desbois et al., (2009)
Haematococcus pluvialis	*Escherichia coli* and *Staphylococcus aureus*	Santoyo et al., (2009)
Skeletonema marinoi	*Listeria monocytogenes*	Terekhova et al., (2009)
Chroococcus dispersus	*Staphylococcus aureus, Staphylococcus epidermidis, Bacillus subtilis, Escherichia coli*, and *Salmonella typhi*	Ghasemi et al., (2007)
Euglena viridis	*Pseudomonas aeruginosa, Vibrio alginolyticus, Vibrio parahaemolyticus*, and *Escherichia coli*	Das et al., (2005)
Chlorella sorokiniana	*Paenibacillus larvae*	Vránová (2017)
Chlorella vulgaris	*Paenibacillus larvae* (spore-forming and vejetatif-forming)	Dostálková et al., (2021)
Porphyridium marinum	*Nosema ceranae*	Roussel et al., 2015
Porphyridium purpureum		

Table 3. Antiviral Effects of Microalgae on Various Bacteria

Microalgae	Viruses It Affects	References
Dunaliella primolecta	*Herpes simplex virus (HSV-1)*	Ohta et al. (1998)
Porphyridium sp.	*Herpes simplex virus (HSV-1, HSV-2), Varicella zoster virus (VZV), VHSV,* and *ASFV*	Huleihel et al. (2001); Fabregas et al. (1999)
Spirulina platensis	*Enterovirus 71*	Shih et al. (2003)
Navicula directa	*HSV-1, HSV-2, Influenza virus,* and *HIV*	Lee et al. (2006)
Gyrodinium impudicum	*Encephalomyocarditis virus (EMCV)*	Yim et al. (2004)
Cochlodinium polykrikoides	*Influenza A/B, Respiratory syncytial virus (RSV),* and *HIV-1*	Hasui et al. (1995)
Arthrospira platensis	*HSV-1, HCMV, Influenza A, Coxsackie, HIV-1, Polio, Measles,* and *Mumps*	Hayashi et al. (1996)
Nostoc flagelliforme	*HSV-1, HSV-2, Human cytomegalovirus,* and *Influenza A*	Kanekiyo et al. (2007)

Furthermore, *nostoflan*, an acidic polysaccharide produced by *Nostoc flagelliforme*, has been identified as an inhibitor of *HSV-1*, *HSV-2*, *human cytomegalovirus*, and *influenza A virus* (Kanekiyo et al., 2007). Studies suggest that its antiviral effect against *HSV* stems from its ability to block viral attachment to host cells.
Despite the significant advancements in this field, various challenges remain. Nevertheless, ongoing research continues to introduce promising new strategies for the sustainable treatment of viral infections, expanding the potential avenues for future scientific progress.

Antifungal effect

Fungal infections are known for their long-term persistence and pathogenic yeasts are a common source of transmission between humans and animals. Infections with Candida spp. are among the most resistant strains, especially in women, and can lead to infertility (Pellati et al., 2008), arthritis (Yordanov et al., 2004) and various organ damage if left untreated. Immunocompromised individuals are more susceptible to fungal diseases caused by yeast and mold spores. Parsiguine, a compound isolated from Fischerella ambigua, and known for its antibacterial properties, has been shown to be effective against the yeast Candida krusei ATCC 44507, and is considered an important antifungal agent (Ghasemi et al., 2004).
In recent studies, ten different strains of microalgae isolated from freshwater sources in Turkey were found to have antifungal activity against the yeast species Saccharomyces cerevisiae, Candida albicans and Candida tropicalis. Among these species, Oscillatoria sp. and Chlorococcus sp. stand out as microalgae with the strongest antifungal activity (Katircioglu et al., 2006). In addition, ethanol extracts of Haematococcus pluvialis were tested on Candida albicans and Aspergillus niger; all extracts were found to be effective against C. albicans but showed no inhibition against A. niger (Santoyo et al., 2009). The compounds responsible for this antifungal activity were butanoic acid and methyl lactate, which were previously known for their antimicrobial properties (Cherrington et al., 1991). In addition, Chlamydomonas reinhardtii, which has a broad spectrum of biological activities, exhibits both antibacterial and antifungal effects. In one study, this microalgae species was found to inhibit the growth of Candida kefyr, Aspergillus niger, and Aspergillus fumigatus (Ghasemi et al., 2007).
In addition, the antifungal effect of the extracts of Scenedesmus obliquus was investigated and in particular the diethyl ether extracts were tested against Aspergillus flavus, Aspergillus steinii, Aspergillus ochraceus, Aspergillus parasiticus, It was found to be effective against fungal species such as Aspergillus westerdijikia, Aspergillus carbonarius, Fusarium verticillioides, Fusarium proliferatum and Penicillium verrucosum (Marres et al., 2019). However, aqueous, methanol, ethanol, acetone and chloroform extract only showed antifungal activity in some fungal species. For example, the aqueous extract proved to be effective against A. flavus, A. steinii, A. westerdijikia and A. carbonarius. Caratungiols A and B isolated from the marine dinoflagellate Amphidinium sp. belong to the class of polyols and studies have shown that caratungiol A at a concentration of 12 µg/disk exhibits antifungal activity on Aspergillus niger (Washida et al., 2006).
According to Abedin and Taha (2008), ethanol, acetone, diethyl ether, and methanol extracts of S. quadricauda exhibited antifungal properties against fungal species such as A. niger, A. flavus, P. herquei, and F. moniliforme. Similarly, Vehapi et al. (2018) found that extracts of Chlorella vulgaris and Chlorella minutissima showed strong antifungal activity against A. niger and Fusarium oxysporum when cultured in iroko tree sap. The study showed that the antifungal activity of these algae species varied when cultured in different media, with lower activity in BBM media and wastewater from Istanbul. In a study conducted by Ghasemi et al. (2007), the antifungal activity of the supernatants of 15 different algae strains was investigated and it was reported that Chlamydomonas reinhardtii, Chlorella dispersus, Chlorella vulgaris, Chlorella sp., Anacystis nidulans, Chlorella ellipsoidea, and Oocystis sp. showed moderate antifungal activity against fungi such as Candida kefyr, Aspergillus fumigatus, and A. niger. However, only the strain C. dispersus 039 proved to be effective against C. albicans, while the other algae extracts showed no activity against C. albicans. These results show that the antifungal activity of microalgae species can be optimized not only with growth media and cultivation techniques, but also with modern molecular biotechnological methods that allow the manipulation of intracellular and extracellular target metabolites.

Table 4. Antifungal Effects of Microalgae on Various Bacteria

Microalgae	Types of Fungi It Affects	References
Fischerella ambigua	*Candida krusei*	Ghasemi et al. (2004)
Oscillatoria sp. and *Chlorococcus sp.*	*Saccharomyces cerevisiae, Candida albicans, Candida tropicalis*	Katircioglu et al. (2006)
Haematococcus pluvialis	*Candida albicans*	Santoyo et al. (2009)
Chrococcus sp. Mogan, Chrococcus sp. Kurtbogazi, Oscillatoria sp.S.F., Oscillatoria sp. Burdur, Oscillatoria sp. Mogan, Oscillatoria limnosa 1966/1380, Anabaena sp.Burdur, Synechocystis aquatilis 1965/426, and *Chlorella vulgaris*	*Bacillus subtilis ATCC 6633, Bacillusthuringiensis RSKK 380, Bacillus cereus RSKK 863, Bacillus megaterium RSKK 578, Yersinia enterocolitica ATCC 1501, Escherichia coli ATCC 11230, Staphylococcus aureus ATCC 25923, Micrococcus luteus NRLL B-4375, Micrococcus flavus, Pseudomonas aeruginosa ATCC29212, Saccharomyces cerevisiae ATCC, Candida albicans, Candida tropicalis*	Katircioğlu et al. (2005)
Chlamydomonas reinhardtii	*Candida kefyr, Aspergillus niger, Aspergillus fumigatus*	Ghasemi et al. (2007)
Scenedesmus obliquus	*Aspergillus flavus, Aspergillus steinii, Aspergillus ochraceus, Aspergillus parasiticus, Fusarium verticillioides*	Marres et al. (2019)

Table 5. Antiprotozoal Effects of Microalgae on Various Bacteria

Microalgea	Protozoa It Affects	References
Amphidinium sp.	*Tritrichomonas foetus*	Washida et al. (2006)
Calothrix sp.	*Plasmodium falciparum*	Rickards et al. (1999)
Fischerella ambigua	*Plasmodium falciparum* and *Trypanosoma rhodesiense*	Perez et al. (1990)
Microcystis aeruginosa	*Plasmodium falciparum* and *Trypanosoma brucei rhodesiense*	Portmann et al. (2008b)
Nostoc sp.	*Plasmodium falciparum*	Barbaras et al. (2008)

Antiprotozoal effect

Protozoal infections are serious health problems that often affect people living in tropical regions. The people most affected by these diseases often live in the poorest parts of the world. Protozoa are single-celled organisms that, like their host cells, are eukaryotic in structure. This makes it difficult to develop effective drugs against protozoa, which have a low risk of toxicity due to their similar cell structure to their host cells. In addition, drug resistance of protozoa is an important issue that needs to be considered. Algae are an inexhaustible source of biologically active compounds (BACs) thanks to their unique physiological properties. For this reason, many researchers worldwide are focusing on the antiprotozoal potential of algae. Most of these studies focus on macroalgae species (Torres et al., 2014). For example, the marine dinoflagellate Amphidinium sp. also exhibits antiprotozoal properties. Caratungiol A from this alga was found to be effective against Tritrichomonas fetus at a concentration of 1 µg/ml (Washida et al., 2006). Another important species, Calothrix sp., synthesizes indole-[3,2-j] phenanthridine compounds called calothrixin A and B, which show antiplasmodial activity against Plasmodium falciparum FAF6 (Rickards et al., 1999). However, Ambigol C, a natural compound isolated from Fischerella ambigua, showed moderate antiprotozoal activity against P. falciparum clone KI (IC50 = 1.5 µg/mL) and NF54 (IC50 = 2.4 µg/mL) strains (Perez et al., 1990). It has also been reported to be moderately effective against Trypanosoma rhodesiense (Wright et al., 2005). Aeracylamides A and B (Portmann et al., 2008a) and compounds C and D were isolated from M. aeruginosa strain PCC 7806 (Portmann et al., 2008b). Of these compounds, aeracylamide B exhibited submicromolar IC50 values against P. falciparum, while aeracylamide C showed low micromolar activity against T. brucei rhodesiense (Portmann et al., 2008b). The β-carboline indole alkaloid nostocarboline, obtained from Nostoc sp. 78-12A, showed significant activity against the P. falciparum K1 strain (Barbaras et al., 2008). This compound showed growth inhibitory properties at nanomolar concentrations against Plasmodium sp.

Table 6. Antiparasitic Effects of Microalgae on Various Bacteria

Microalgea	Parasites It Affects	References
Cladophora crispata	*Echinococcus granulosus* (Hydatid cyst)	Athbi et al. (2014)
Chlorella vulgaris	*Steinernema feltiae* (Nematode)	Zielinsky et al. (2020)
Chroococcus minutus, Calothrix parietina, and *Gloeocapsa gigantea*	*Varroa destructor*	Hassan and Mahmoud (2006)

Antiparasitic effect

In addition to their antiprotozoal properties, compounds can also be isolated from algae and microalgae that are effective against multicellular parasitic organisms, especially parasitic animals. For example, alkaloid and ethyl acetate extracts from Cladophora crispata have been found to reduce the number and weight of hydatid cysts caused by Echinococcus granulosus (Athbi et al., 2014). In this study, the efficacy of these extracts was compared with the commonly used antiparasitic drug albendazole. Although the lowest number of cysts and the smallest cyst sizes after treatment were found in the albendazole-treated group, alkaloid and ethyl acetate extracts showed a similar effect.

Recent studies have shown that extracts of Chlorella vulgaris have a toxic effect on the nematode Steinernema feltiae (Zielinsky et al., 2020). These nematodes infect insects and kill their hosts through entomopathogenic bacteria. In the study, it was observed that hydrophilic extracts of C. vulgaris completely killed S. feltiae when applied at concentrations of 37.5, 75, and 150 mg/mL. Parasitic diseases are not only a major public health problem for humans, but also of great importance for domestic animals and agricultural production. Previous research shows that antiparasitic agents from the microalgae have been studied more than those from the microalgae. Therefore, further investigation of the antiparasitic potential of microalgae could contribute to the development of new treatment options in the future. Studies conducted mainly on honeybees (*Apis mellifera*) have shown that microalgae can be effective in controlling Varroa destructor mites. A lower infestation rate was found in hives fed with algae than in untreated hives. In colonies fed with the species Chroococcus minutus, Calothrix parietina, and Gloeocapsa gigantea, the average mite infestation rate was 2.7, compared to 26.26% in untreated control colonies. In the same study, a mite infestation rate of 2.9% was recorded in hives treated with oxalic acid (Hassan and Mahmoud, 2006). These data indicate that the antiparasitic potential of microalgae is considerable and that their effect against different parasite species should be investigated in more detail.

Conclusion

In recent years, parasitic, fungal, and bacterial pathogens threatening bee health have necessitated innovative solutions beyond conventional treatment methods. In this context, microalgae stand out as a multifaceted tool for bee health management, not only due to their nutritional value but also their antiparasitic, antifungal, and antibacterial properties. Studies reveal that microalgae species such as *Spirulina platensis*, *Chlorella vulgaris*, and *Nannochloropsis* exhibit inhibitory effects against common bee parasites like *Nosema ceranae*. Moreover, phenolic compounds, polysaccharides, and antimicrobial peptides in microalgal extracts demonstrate antifungal and antibacterial activity against pathogens such as *Ascosphaera apis* (chalkbrood) and *Paenibacillus larvae* (American foulbrood). These bioactive components may enhance individual and colony-level immunity by modulating bees' defense mechanisms. The therapeutic potential of microalgae could reduce reliance on chemical treatments, minimizing residue and resistance risks. However, further research is needed to elucidate their mechanisms of action, optimize dosages, and validate efficacy under field conditions. Investigating synergistic effects of different microalgae strains or their combination with probiotics represents a promising future direction. In conclusion, microalgae are not merely a nutritional supplement but also a natural bioprotective agent for beekeeping. Integrating microalgae-based strategies into sustainable apiculture could offer economic and ecological advantages. Advancing research in this field may revolutionize honeybee health management practices.

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Development of a Practical Model to Evaluate the Influence of Abiotic Factors on Subclinical Mastitis in Dairy Farms in Albania.[1]

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Abstract

Background and aim of study: Mastitis poses a major challenge in Albanian dairy farming, with subclinical mastitis (SCM) causing significant economic losses due to undetected infections. It results from interactions among environmental factors, pathogens, and host immunity. Contagious pathogens are often transmitted during milking, whereas environmental sources include bedding and manure. Research and practice have primarily concentrated on contagious microorganisms, with limited exploration of environmental factors affecting mastitis susceptibility and treatment efficacy. In Albanian dairy farms, subclinical mastitis (SCM) is frequently underdiagnosed due to insufficient awareness among farmers and veterinary professionals. Additionally, a standardized national surveillance system for SCM prevalence is absent. A comprehensive approach integrating both biotic and abiotic factors, as demonstrated in other countries, is crucial for addressing this issue under real farm conditions. Therefore, this study is undertaken with the aim of developing a practice-relevant methodological model for farmers and professionals to conduct an integrated assessment of the biotic and abiotic factors contributing to the occurrence of subclinical mastitis in dairy farms in Albania.

Methodology: This model quasi-protocol integrates a range of practical tools, including questionnaires for both quantitative and qualitative data collection, direct testing on dairy farms and animals, and rapid analytical methods for milk and feed samples. Additionally, professional evaluations from veterinarians or animal science experts are conducted, with findings communicated to farmers in an simple practical format. The implementation of the protocol involves the following steps: 1st step) collection of farmer information; 2nd) random selection of cows for testing; 3rd) on-farm assessment of clinical mastitis, udder and milking hygiene, and stable hygiene; 4th) administration of the California Mastitis Test (CMT); 5th) collection of milk samples from cows with subclinical mastitis (SCM) for agent investigation and rapid physicochemical testing; and 6th) evaluation of herd feeding status and feed quality through organoleptic assessment and rapid analysis using NIRS equipment.

Results: This practical model was tested in a study on nine Holstein dairy farms in Albania, spanning both lowland regions (Durrës and Shkodra) and hilly areas (Korça). The study involved measurements taken over 8 months of lactation, up to the onset of the dry period. On each farm, 6-10 cows in lactations 1-3 were randomly selected for CMT tests and milk sampling. The average productivity parameters were as follows: herd size ranged from 21 to 140 cows; daily milk production ranged from 12 to 30 kg; and the average days in lactation were 32-83 for the first measurement, 146-213 for the second, and 241-300 for the third. To assess the relationship between subclinical mastitis (SCM) and milk physicochemical properties under real farm conditions, no changes were made to housing, hygiene, or feeding practices, though these factors were documented. Variance and regression analyses using SPSS were conducted to evaluate the influence of biotic and abiotic factors on SCM and their interactions with other variables. The study concludes that this protocol is practical and easily applicable on Albanian dairy farms, for veterinarians, zootechnicians, and trained farmers alike.

Keywords: *subclinical mastitis; dairy cows; biotic and abiotic factors;*

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Investıgatıon of the Effects of Propolis on Some Blood Parameters in Rainbow Trout (*Oncorhynchus Mykiss*) Exposed to Long-Term Bısphenol-A

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Introduction

In recent years, studies have revealed the harmful effects of Bisphenol-A (BPA), whose use and production have increased, on living organisms. Many chemicals, like BPA, designed to simplify life, adversely affect it. Therefore, it is needed to identify alternative substances to replace these chemicals or to develop new compounds that can mitigate their harmful effects. Research has shown that many food products with antioxidant properties can counteract the toxic effects of xenobiotics. One such product is propolis, which has been used in alternative medicine for many years. It aims to investigate the effects of BPA long term sexposure on certain blood parameters in rainbow trout. Additionally, it seeks to explore the potential protective role of propolis in alleviating these harmful effects.

Material-Method

Rainbow trout were used as the experimental material in this study. The experimental setup consisted of a total of 8 groups, including fish exposed to BPA concentrations of 500, 1000, and 1500 µg/L, as well as BPA + propolis groups, where fish were fed with propolis-supplemented feed during the exposure. It lasted for 7 weeks. After experiment, blood samples were collected following the dissection of the fish, centrifuged, and analyzed for the necessary blood parameters.

Results

It was observed that different doses of BPA and propolis applied to rainbow trout affected the values of certain blood parameters following chronic toxicity exposure. The blood values obtained from the fish were analyzed and statistically evaluated.

Conclusion and Discussion

After analyses, different doses of BPA increased the levels of certain blood parameters in fish, indicating toxic effects. Other groups treated with propolis, a natural antioxidant, showed reduced levels of these blood parameters. Consequently, it can be stated that the application of propolis mitigated the toxicity caused by BPA in rainbow trout.

***Keywords**: Bisphenol A, Rainbow trout, Blood tissue, Propolis, Toxicity*

Ethical Statement
This study was reviewed and approved by Van Yüzüncü Yıl University Aquatic Vertebrate Local Ethics Committee (Yüsocyek) (Decision No: 224/08-05).

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Bisfenol-A'ya Uzun Süreli Maruz Kalan Gökkuşağı Alabalığında (*Oncorhynchus Mykiss*) Propolisin Bazı Kan Parametreleri Üzerine Etkilerinin Araştırılması

Giriş

Son yıllarda kullanım alanı ve üretimi artış gösteren Bisfenol-A (BPA)'nın canlılar üzerindeki zararlı etkileri yapılan çalışmalarla ortaya konmuştur. BPA gibi hayatı kolaylaştırmak adına üretilen pek çok kimyasal hayatı olumsuz yönde etkilemektedir. Bu kimyasalların yerine konulacak alternatif maddelerin en kısa zamanda bulunması veya zararlı etkilerini azaltacak yeni maddelere ihtiyaç duyulmaktadır. Yapılan çalışmalarda ksenobiyotiklerin zararlı etkilerini giderecek antioksidan özellikte pek çok gıda ürünü bilinmektedir. Bunlardan birisi uzun yıllar alternatif tıpta kullanılan propolistir. Bu çalışma, BPA' nın uzun süreli maruziyetinin Gökkuşağı alabalığı üzerindeki bazı kan parametreleri açısından etkilerini incelemeyi amaçlamaktadır. Aynı zamanda, bu zararlı etkilerin hafifletilmesinde propolisin potansiyel koruyucu rolünü araştırmayı hedeflemektedir.

Materyal-Metot

Çalışmada materyal olarak Gökkuşağı alabalığı kullanılmıştır. Deney düzeneği, balıkların 500, 1000 ve 1500 µg/L BPA konsantrasyonlarına maruz bırakıldığı ve BPA + propolis gruplarının bu süreçte propolis ilaveli yemlerle beslendiği toplamda 8 gruptan oluşup 7 haftalık bir maruziyet süresini kapsamaktadır. Deney sonunda balıkların diseksiyon işlemin ardından kan örnekleri alınarak santrifüj edilip, gerekli kan parametreleri analiz edilmiştir.

Bulgular

Gökkuşağı alabalığına uygulanan farklı dozlardaki BPA ve propolis dozlarının kronik toksisite maruziyetinin ardından bazı kan parametrelerindeki değerleri etkilediği gözlemlendi. Balıklardan alınan kan değerlerinin veri analizi yapılarak istatiksel açıdan değerlendirilmesi yapıldı.

Sonuç ve Tartışma

Yapılan analizler sonucunda farklı dozlarda uygulanan BPA dozlarının balıkların bazı kan parametlerini seviyelerini artırarak toksitite etkisi yaptığını ve doğal bir antioksidan olan propolis uygulanan gruplarda ise bu kan parametrelerinin değerlerinin azaldığı gözlemlendi. Sonuç olarak, propolis uygulamasının Gökkuşağı alabalıklarında BPA'nın neden olduğu toksisiteyi azalttığı söylenebilir.

Anahtar Kelimeler: *Bisfenol A, Gökkuşağı alabalığı, Kan doku, Propolis, Toksisite*

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ID: 334

The Impact of Climate Change on Agricultural Insurance: The Role of Artificial Intelligence

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Abstract

Climate change has significantly increased the frequency and severity of extreme weather events, posing serious risks to agricultural production and food security. Agricultural insurance plays a crucial role in mitigating financial risks for farmers by compensating for climate-related losses. However, the unpredictability of climate patterns challenges traditional risk assessment and premium calculation methods, threatening the sustainability of agricultural insurance systems. Recent advancements in Artificial Intelligence (AI) offer innovative solutions to enhance risk prediction, optimize premium pricing, and improve claims management. AI-driven models, utilizing machine learning and big data analytics, enable more accurate weather forecasting, early warning systems, and real-time damage assessments. This study explores how AI can strengthen agricultural insurance against climate change-induced uncertainties. Additionally, it discusses policy recommendations and technological innovations to enhance the resilience and efficiency of agricultural insurance systems in the face of climate change.

Keywords: *Climate change, artificial intelligence, agricultural insurance, risk assessment, machine learning, predictive modeling.*

İklim Değişikliğinin Tarım Sigortaları Üzerine Etkisi: Yapay Zekanın Rolü

Özet

İklim değişikliği, aşırı hava olaylarının sıklığını ve şiddetini artırarak tarımsal üretim ve gıda güvenliği üzerinde ciddi riskler oluşturmaktadır. Tarım sigortaları, çiftçilerin iklim kaynaklı kayıplarını telafi ederek finansal riskleri azaltmada önemli bir rol oynamaktadır. Ancak iklim değişikliğinin öngörülemez doğası, geleneksel risk değerlendirme ve prim hesaplama yöntemlerini zorlaştırarak tarım sigortalarının sürdürülebilirliğini tehdit etmektedir. Yapay Zeka (YZ), risk tahminlerini iyileştirmek, prim hesaplamalarını optimize etmek ve hasar yönetimini geliştirmek için yenilikçi çözümler sunmaktadır. Makine öğrenmesi ve büyük veri analitiği ile desteklenen YZ tabanlı modeller, daha doğru hava tahminleri, erken uyarı sistemleri ve gerçek zamanlı hasar tespitleri sağlamaktadır. Bu çalışma, yapay zekanın iklim değişikliği kaynaklı belirsizlikler karşısında tarım sigortalarını nasıl güçlendirebileceğini incelemektedir. Ayrıca, tarım sigortalarının dayanıklılığını ve verimliliğini artırmak için politika önerileri ve teknolojik yenilikler ele alınmaktadır.

Anahtar Kelimeler: *İklim değişikliği, yapay zeka, tarım sigortaları, risk değerlendirme, makine öğrenmesi, öngörüsel modelleme.*

Giriş

İklim değişikliği, tarım sektöründeki risk yapısını kökten değiştirmektedir. Kuraklıklar, seller ve fırtınalar gibi aşırı hava olaylarının sıklığı ve şiddeti artmış; bu durum hem çiftçiler hem de sigortacılar için benzeri görülmemiş zorluklar yaratmıştır. Birleşmiş Milletler Gıda ve Tarım Örgütü'ne (FAO) göre, doğal afetlerin yıllık meydana gelme oranı 1970'ler ve 1980'lere kıyasla şu anda üç kat daha fazladır. Tarım sektörü bu etkilerden orantısız şekilde etkilenmekte olup, afet kaynaklı kayıpların yaklaşık %63'ünü üstlenmektedir. Özellikle kuraklık, küresel ölçekte tarımsal üretim kaybının en büyük nedeni olarak öne çıkmaktadır.

İklim değişkenliğinin artması sonucu, ürün verimlerinde daha fazla dalgalanma yaşanmakta ve felaket düzeyinde kayıplar daha sık meydana gelmektedir. Bu durum, verim kayıplarının ve piyasa dalgalanmalarının öngörülemez hale gelmesine yol açmaktadır. Sektör uzmanlarının ifadelerine göre, küresel ısınma hava olaylarını giderek daha "öngörülemez" ve yıkıcı hale getirmiştir; bu da, geleneksel olarak istikrarlı risk istatistiklerine dayanan sigortacılık sektörüne derin bir belirsizlik enjekte etmektedir.

Gerçekten de, iklim değişikliği tarihsel modellere olan güveni sarsarken, sigortacılar "güven krizine" girmiştir. Bu istikrarsızlık, sigorta tazminatlarının ve primlerinin yükselmesine yol açmakta; hatta bazı sigortacıları yüksek riskli bölgelerden çekilmeye zorlamaktadır.

Tarım sigortası, çiftçilerin geçim kaynaklarını bu tür tehlikelere karşı koruyan kritik bir risk yönetim aracı olarak hizmet vermektedir. Kanıtlar, iklim değişikliğinin tarımsal üretimi ve gıda güvenliğini olumsuz etkilediğini, ancak

tarım sigortasının bu olumsuz etkileri hafifletebildiğini göstermektedir. Başka bir deyişle, etkili sigorta koruması, çiftçilerin iklim şoklarına karşı dayanıklılık geliştirmelerine yardımcı olur.

Bununla birlikte, geleneksel sigorta modelleri ve fiyatlandırma stratejileri, geçmişteki hava ve verim verilerine dayanıyordu ve bu yaklaşım günümüzde yetersiz kalmaktadır. Geçmişteki istatistiksel ilişkiler, değişen iklim desenleri karşısında artık daha az öngörücü hale gelmiştir; eski aktüeryal modeller yeni aşırılıklar ve oynaklıklar nedeniyle geçerliliğini yitirmiştir. Son dönem raporlarına göre, aşırı olayların hızla artan temposu, sigortacıları ürünlerini çok daha değişken bir çevreye göre yeniden tasarlamaya zorlamaktadır. Basitçe ifade etmek gerekirse, yalnızca geçmiş veriler artık değişen iklim koşullarında riskin tam bir resmini sunmamaktadır. Sigortacıların, ayakta kalabilmek için ileriye dönük iklim projeksiyonlarını da hesaba katmaları ve yeni yöntemler benimsemeleri gerekmektedir.

Bu noktada Yapay Zekâ (YZ) teknolojileri, tarım sigortasını bu zorluklar karşısında güçlendirmek için umut verici bir çözüm olarak ortaya çıkmıştır. Makine öğrenmesi ve veri analitiği gibi YZ teknikleri, karmaşık iklim verilerini analiz etmenin, yeni desenleri tespit etmenin ve geleneksel yöntemlerin ötesinde öngörü doğruluğunu artırmanın yenilikçi yollarını sunmaktadır. Sigorta sektöründe YZ, risk değerlendirmesinden poliçe düzenlemeye, prim hesaplamadan hasar yönetimine kadar değer zincirinin her aşamasında iyileştirme sağlayabilir.

Bu çalışma, iklim değişikliğinin tarım sigortası üzerindeki etkisini incelemekte ve YZ araçlarının sektöre nasıl uyum sağlama imkânı sunduğunu tartışmaktadır. İlerleyen bölümlerde, YZ'nin tarım sigortasına uygulanma yöntemleri özetlenecek, kuraklık risk tahmini için küçük ölçekli bir örnek model sunulacak ve ardından bu örneğin sonuçları ile YZ'nin risk değerlendirme, prim fiyatlandırması ve hasar işleme süreçleri üzerindeki daha geniş etkileri tartışılacaktır. Son bölümde ise anahtar bulgular ve öneriler sunulacaktır.

Tarım Sigortaları (Tarsim)

TARSİM (Tarım Sigortaları Havuzu) tarafından sunulan Bitkisel Ürün Sigortası, çiftçilerin doğal afetler ve çeşitli riskler nedeniyle karşılaşabilecekleri maddi kayıpları güvence altına almayı amaçlayan bir sigorta türüdür. Tarım ve Orman Bakanlığı'nın belirlediği kayıt sistemlerine kayıtlı parsellerde (açık alan) yetiştirilen bitkisel ürünler, meyve ağaçları, çay ve asmalar ile fidanlar bu sigorta kapsamında değerlendirilmektedir.

Teminat Kapsamındaki Riskler

Sigorta, aşağıdaki risklerin neden olacağı maddi zararları sigorta bedeline kadar teminat altına alır:

- Dolu, fırtına, hortum, yangın, deprem, heyelan, taşıt çarpması, sel ve su baskını nedeniyle ürünlerde meydana gelen miktar kaybı
- Dolunun yaş meyve, yaş sebze ve kesme çiçeklerde neden olduğu kalite kaybı
- Yaban domuzu ve geyik gibi yabani hayvanların tarla ürünleri, sebzeler, fidanlar ve çilekte neden olduğu miktar kaybı
- Kuşların, ayçiçeği ürünlerinin olgunlaşma ve hasat döneminde tohumları yemesiyle oluşan miktar kaybı
- Yağmurun, pamuk ve pamuk (sertifikalı tohumluk) ürünlerinde kozaların açılmasından itibaren hasada kadar olan dönemde neden olduğu miktar kaybı
- Don riskinin, meyve fidanları ve bağ fidanlarında neden olduğu miktar kaybı

İsteğe Bağlı Ek Teminatlar

Ek prim ödemesiyle aşağıdaki riskler de teminat kapsamına alınabilir:

- Don riskinin yaş meyveler, yağ gülü ve enginarda neden olduğu miktar kaybı
- Dolu ağı ve örtü ile destek (telli terbiye) sistemleri ve bu sistemlerin altında bulunan ürünlerde; dolu, dolu ağırlığı, kar ağırlığı, fırtına, hortum, yangın, deprem, heyelan, sel ve su baskını, taşıt çarpması risklerinin neden olduğu zararlar
- Yağmur riskinin; kiraz ve üzüm ürünlerinde olgunlaşma ve hasat dönemlerinde neden olduğu miktar kaybı ile taze tüketime yönelik olarak üretilen incirlerde olgunlaşma ve hasat dönemlerinde yol açtığı kalite kaybı, kurutmalık amaçlı üretilen incirlerde olgunlaşma ve buruklaşma dönemlerinden hasada kadar olan dönemde neden olduğu miktar ve kalite kaybı
- Dolu, fırtına, hortum, yangın, deprem, heyelan, taşıt çarpması, sel ve su baskını, yaban domuzu zararı risklerinin, arpa, buğday, çavdar, tritikale, yulaf ve kaplıca buğday ürünleri ile bu ürünlerin sertifikalı tohumluklarının sap kısmında neden olduğu miktar kaybı
- Dolu, fırtına, hortum, yangın, deprem, heyelan, taşıt çarpması, sel ve su baskını risklerinin, salamuralık yaprak üretimi yapılan asmaların yapraklarında neden olduğu miktar kaybı
- Sıcak havanın, altıntop, limon, mandalina, portakal ürünlerinde çiçeklenme, meyve tutumu ve küçük meyve dönemlerinde kuruma, dökülme; üzümlerde ise çiçeklenme ve tane bağlama dönemlerinde salkımlarda tane tutumunun gerçekleşmemesi ve tanede büyümenin durması, kuruması ve dökülmesi şeklinde neden olduğu miktar kaybı
- Don riskinin, şekerpancarı, kabak (çerezlik), domates, biber, patlıcan, kavun, karpuz, patates ürünlerinde fide ve yapraklanma döneminde yeniden ekim dikime neden olacak şekilde meydana getirdiği zararlar

Devlet Desteği
Bitkisel Ürün Sigortası'nda üreticilerin priminin %50'si, meyvelerde ise don teminatı priminin %67'ye varan kısmı devlet tarafından karşılanmaktadır.

İklim Değişikliği ve Tarım Üzerindeki Etkileri

İklim değişikliği, tarımda riskleri çeşitli mekanizmalar yoluyla artırmaktadır. Bu etkiler Tablo 1'de özetlenmiştir.

Tablo 1. İklim Değişikliğinin Tarımsal Üretim Üzerindeki Etkileri

Etki Kategorisi	Açıklama
Sıcaklık Artışı	Bitkilerde ısı stresi, büyüme dönemlerinin kısalması
Yağış Desenlerinde Değişim	Artan kuraklık ve sellerin toprak ve ürünler üzerindeki olumsuz etkileri
Artan Zararlı ve Hastalıklar	Zararlı ve hastalıkların yaygınlığında değişimler
Aşırı Hava Olayları	Fırtına, dolu, don gibi olayların ani kayıplara yol açması

(Kaynak: IPCC, 2022'den uyarlanmıştır)

Elif Çekici (2009), tarımın iklim değişkenliklerine en duyarlı sektörlerden biri olduğunu vurgulamış; kuraklıkların, sellerin ve beklenmeyen don olaylarının ürün verimlerinde ciddi düşüşlere yol açtığını belirtmiştir. Damlama sulama gibi teknolojik ilerlemelere rağmen, çiftçiler doğadan kaynaklanan riskleri tamamen ortadan kaldıramamaktadır.

Tarım Sigortası Üzerindeki Etkiler

İklim değişikliği, tarım sigortası sistemleri üzerinde baskı oluşturarak hasarların sıklığını ve şiddetini artırmaktadır. Başlıca etkiler şunlardır:

- Hasar Sıklığında Artış: Aşırı hava olaylarının daha sık meydana gelmesi, hasar taleplerinin artmasına yol açmaktadır (Torusdağ ve diğ., 2024).
- Öngörülebilirlikte Azalma: Tarihsel modellere olan güven azalmakta, bu da risk değerlendirmesini zorlaştırmaktadır (Torusdağ ve diğ., 2024).
- Prim Artışları: Yükselen riskler, sigorta primlerinin yükselmesine neden olmakta ve çiftçiler için sigorta erişimini zorlaştırmaktadır (Torusdağ ve diğ., 2024).

Türkiye'de tarım sigortası, 2005 yılında devlet destekli sigortanın TARSİM (Tarım Sigortaları Havuzu) aracılığıyla devreye girmesiyle önemli ölçüde ivme kazanmıştır. Şengün ve Özden'e (2022) göre, mevcut sigorta programlarına rağmen çiftçiler sigortayı genellikle pahalı bulmakta ve kapsamı yetersiz olarak değerlendirmektedir; bu da politika tasarımı ile çiftçi beklentileri arasında önemli boşluklar olduğunu göstermektedir.

Tablo 2. İklim Değişikliği Altında Tarım Sigortasının Karşılaştığı Zorluklar

Zorluk	Sonuç
Hasar Sıklığında Artış	Primlerin Yükselmesi ve Kapsamın Daralması
Risk Öngörülebilirliğinin Azalması	Poliçe Düzenleme (Underwriting) Zorlukları
Çiftçi Algı Problemleri	Düşük Katılım Oranları

Ayrıca, Çekici (2009) tarım sigortalarının, iklim değişikliğinin etkilerine karşı anlamlı olabilmesi için, kuraklığa bağlı verim kayıplarına karşı da koruma gibi daha geniş kapsamlar içerecek şekilde evrilmesi gerektiğini vurgulamıştır.

Yapay Zeka'nın Tarım Sigortasında Kullanımı
İklim değişikliğinin yarattığı yeni risk ortamında, geleneksel tarım sigortası yöntemleri artık yeterli gelmemektedir. Yapay Zeka (YZ), bu zorlukların aşılmasında güçlü bir çözüm aracı olarak öne çıkmaktadır. YZ teknikleri, tarım sigortasında birçok aşamada etkili bir şekilde kullanılabilir:
a) Risk Değerlendirme ve Önceden Tahmin
Makine öğrenmesi ve veri analitiği yöntemleri sayesinde çok büyük ve karmaşık iklim, toprak ve ürün verileri analiz edilebilir. Bu sistemler:

- Geçmiş hava olayları ile ürün zararları arasındaki ilişkileri daha doğru biçimde modelleyebilir.
- Geleneksel aktüeryal (sigorta matematiği) modellerin ötesine geçerek, gelecekteki riskleri iklim projeksiyonlarına dayalı olarak öngörebilir.
- Yeni gelişen riskleri (örneğin, farklı bölgelerde yaygınlaşmaya başlayan zararlı hastalıklar) erken tespit edebilir.

b) Prim Fiyatlandırması
Yapay zeka sistemleri:
- Her çiftçi, ürün türü ve coğrafi bölge için kişiselleştirilmiş risk puanları oluşturabilir.
- Böylece prim hesaplamalarını daha adil ve hassas hale getirerek, aşırı prim artışlarının önüne geçebilir.
- Özellikle küçük ölçekli üreticiler için daha erişilebilir sigorta paketleri tasarlanmasına olanak tanır.

c) Hasar Tespiti ve Tazminat Süreçleri
- Uydu görüntüleri, insansız hava araçları (drone) verileri ve IoT (Nesnelerin İnterneti) sensörlerinden toplanan bilgiler, YZ ile analiz edilerek hızlı ve doğru hasar tespiti yapılabilir.
- Yapay zeka tabanlı sistemler, sahada birebir ekspertiz ihtiyacını azaltabilir, böylece hasar ödemeleri çok daha hızlı gerçekleşir.
- Bu, çiftçilerin gelir kaybını hızla telafi etmelerine yardımcı olur ve sigortaya olan güveni artırır.

d) Sahtekârlık Önleme
- YZ algoritmaları, olağan dışı hasar başvurularını ve dolandırıcılık şüphelerini erken aşamada tespit edebilir.
- Böylece sistemin finansal sürdürülebilirliği korunmuş olur.

Küçük Ölçekli Uygulama: Kuraklık Riski Tahmin Modeli
Bu çalışmada, YZ'nin tarım sigortasına uygulanabilirliğini göstermek amacıyla küçük ölçekli bir kuraklık risk tahmin modeli geliştirilmiştir. Model, geçmiş yıllara ait sıcaklık, yağış ve toprak nem verilerini kullanarak, belirli bölgelerdeki kuraklık olasılığını tahmin etmektedir. Bu tür modeller:
- Kuraklık teminatlı sigorta ürünlerinin daha hassas ve gerçekçi şekilde yapılandırılmasını sağlar.
- İleriye dönük tarımsal üretim planlaması ve devlet destekli sigorta programlarının daha etkin hale getirilmesine katkı sunar.

Sonuç

İklim değişikliği, tarımsal sürdürülebilirlik ve bunu destekleyen sigorta sektörü için giderek büyüyen bir tehdit oluşturmaktadır. Tarihsel iklim istikrarına dayanan geleneksel sigorta modelleri, artık etkili olma özelliğini büyük ölçüde yitirmiştir. Tarım sigortasının geleceğini güvence altına almak için, yeni teknolojileri, kamu-özel sektör iş birliğini ve çiftçi katılımını içeren dinamik ve ileriye dönük yaklaşımlar gereklidir. Yapay zeka modellerinin çığır açan sonuçları, sigorta tahmin modellerine olası entegrasyonları açısından bilimsel olarak detaylı bir şekilde incelenmelidir.

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Extraction and Isoelectric Precipitation of Protein from Hazelnut Meal

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Abstract

This study investigates the two-stage protein extraction from hazelnut meal and the evaluation of isoelectric precipitation efficiency. In the first extraction stage, proteins were extracted at pH 8, 9, and 10 for one hour, followed by a second extraction on the residual solids. The first extraction yielded 9649, 10238, and 10355 mg/mL at pH 8, 9, and 10, respectively, indicating increased solubility at higher pH. The second extraction recovered additional protein but with lower efficiency, yielding 8599, 8677, and 8838 mg/mL at pH 8, 9, and 10, respectively. A two-stage extraction was found to enhance overall protein recovery, but further extractions beyond this point may not be efficient. The study also examined the precipitation efficiency at the isoelectric point (pI = 4.5). After the first extraction, supernatant protein concentrations were 291, 279, and 299 mg/mL at pH 8, 9, and 10, demonstrating effective precipitation. Similar results were obtained for the second extraction, confirming the efficiency of the precipitation step. Additionally, proteins extracted at pH 10 were precipitated at different pH values, with supernatant concentrations of 644 (pH 3.5), 341 (pH 4), 336 (pH 4.5), and 347 mg/mL (pH 5). These findings highlight that a pH 9-10 extraction followed by precipitation at pH 4.5 maximizes protein recovery and precipitation efficiency. The study provides insights into optimizing protein isolation from hazelnut meal for potential applications in food processing.

Key Words: *Hazelnut meal, protein extraction, isoelectric precipitation, pH optimization, protein recovery.*

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Combine Activated Carbon and Calcium Hydroxide to Lower the Salinity of Irrigation Water

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Abstract

High salt concentrations in irrigation water in arid regions can lead to significant nutritional imbalances, adversely affecting plant growth and productivity. The use of such water can also cause sodium fixation in soil, contributing to salinization that degrades soil quality, resulting in clay dispersion, structural deterioration, reduced permeability, and plant asphyxiation. Our treatment method combines activated carbon and calcium hydroxide, leveraging activated carbon's high adsorption capacity for chemical compounds. Calcium hydroxide ($Ca(OH)_2$) is an effective, cost-efficient alkaline product that enhances water quality by neutralizing acidity, softening, purifying, and removing turbidity and impurities. In our methodology, we activate charcoal from palm residues with citric acid and mix it with calcium hydroxide to reduce chloride levels, resulting in clean water that meets salinity standards. The application of this mixture to saline irrigation water yielded a 20-40% reduction in ion levels (calcium, magnesium, sodium, potassium, carbonate, and bicarbonate), demonstrating the treatment's effectiveness. These results support the design considerations for using activated carbon from palm residues alongside calcium hydroxide to lower salinity levels. Given these promising findings, further research is necessary to assess the long-term stability of the treated water and its suitability for various agricultural applications. We plan to conduct field trials to evaluate the treatment's performance under different environmental conditions and its effects on soil health and crop yield. Additionally, we will analyze the economic feasibility of scaling up the process, taking into account raw material costs and potential benefits for farmers facing salinity challenges.

In conclusion, our initial findings indicate that utilizing activated charcoal derived from palm residues in combination with calcium hydroxide presents a viable solution for salinity remediation in irrigation. This eco-friendly approach not only helps manage saline water but also promotes agricultural waste recycling, contributing to a more sustainable farming future.

Keywords: salinity, irrigation water, activated charcoal, citric acid, Calcium hydroxide.

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Food Safety in Hazelnut Enterprises: Risks and Solution Suggestions

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Abstract

This study examines food safety in hazelnut firms, the associated hazards, and the techniques for risk management. In sensitive agricultural goods like hazelnuts, aflatoxin contamination, microbiological and chemical hazards, hygiene inadequacies, and environmental factors are significant threats to food safety. Mitigating these dangers is essential not only to safeguard consumer health but also to enhance Türkiye's worldwide trade potential in the hazelnut industry. The research underscores the necessity of adopting international standards like HACCP and ISO 22000 in hazelnut firms, asserting that contemporary processing and storage methods enhance product quality by maintaining circumstances of low temperature and relative humidity. Moreover, stringent regulation of pesticides, the establishment of routine testing techniques, and adherence to hygiene standards are advised to avert chemical and microbiological contamination. Enhancing employee hygiene awareness and environmental sanitation contributes to the sustainability of food safety in organizations. The implementation of modern technology, including sensor-based monitoring systems and inert gas atmospheres, along with adherence to international food safety regulations, is essential for ensuring safe production processes and enhancing competitiveness in hazelnut firms. Therefore, ensuring food safety in hazelnut operations not only protects consumer health but also plays a crucial role in maintaining the sustainability of Türkiye's agricultural exports.

Keywords: *Hazelnut enterprises, food safety, food safety management systems, ISO 22000, Hygiene and Sanitation*

Fındık İşletmelerinde Gıda Güvenliği: Riskler ve Çözüm Önerileri

Özet

Bu çalışma, fındık işletmelerinde gıda güvenliği kavramını, karşılaşılan riskleri ve bu risklerin yönetimine yönelik stratejileri ele almaktadır. Fındık gibi hassas tarımsal ürünlerde afla toksin kontaminasyonu, mikrobiyolojik ve kimyasal riskler, hijyen eksiklikleri ve çevresel faktörler, gıda güvenliğini tehdit eden en önemli unsurlar arasında yer almaktadır. Bu risklerin kontrol altına alınması, yalnızca tüketici sağlığını korumakla kalmayıp, Türkiye'nin fındık sektöründeki uluslararası ticaret kapasitesini artırmak için de bir zorunluluktur. Araştırmada, HACCP ve ISO 22000 gibi uluslararası standartların fındık işletmelerinde uygulanmasının önemi vurgulanmakta; modern işleme ve depolama tekniklerinin, düşük sıcaklık ve bağıl nem gibi koşulların sağlanmasıyla ürün kalitesini artırdığı ifade edilmektedir. Ayrıca, kimyasal ve mikrobiyolojik kontaminasyonların önlenmesi için tarım ilaçlarının sıkı denetimi, düzenli test protokollerinin uygulanması ve hijyen standartlarına uyum önerilmektedir. Çalışanların hijyen farkındalığının artırılması ve çevresel hijyenin iyileştirilmesi de işletmelerde gıda güvenliğinin sürdürülebilirliğine katkı sağlamaktadır. Sonuç olarak, yenilikçi teknolojilerin (örneğin, sensör tabanlı izleme sistemleri ve inert gaz atmosferleri) benimsenmesi ve uluslararası gıda güvenliği standartlarına uyum, fındık işletmelerinde güvenli üretim süreçlerinin sürdürülmesi ve rekabet gücünün artırılması açısından kritik bir rol oynamaktadır. Bu bağlamda, fındık işletmelerinde gıda güvenliğinin sağlanması, yalnızca tüketici sağlığını korumakla sınırlı kalmayıp, aynı zamanda Türkiye'nin tarımsal ihracatında sürdürülebilirliği sağlamanın temel taşlarından biri olarak değerlendirilmektedir.

Anahtar Kelimeler: *Fındık işletmeleri, gıda güvenliği, gıda güvenliği yönetim sistemleri, ISO 22000, Hijyen ve Sanitasyon*

Giriş

Corylus avellana familyasında yer alan ve cevizle birlikte Avrupa'da yetiştiriciliği en fazla yapılan kuruyemiş olan fındığın en önemli üreticisi Türkiye'dir (% 62). Türkiye'yi İtalya (% 13), ABD (%6), Azerbaycan (%5), Şili (%3), Gürcistan (%3) ve Çin (%2) takip etmektedir (Karaosmanoğlu, 2025). Avrupa açısından ekonomik önemine ilaveten, fındık içerdiği tekli doymamış yağ asitleri, tokoferoller, fitosteroller gibi yağ bileşenlerinin yanı sıra biyolojik olarak aktif polifenoller gibi fitokimyasallar nedeniyle insan beslenmesi açısından önemli bir role sahiptir (Karaosmanoğlu, 2024; Karaosmanoglu 2023a). Yüksek oranda yağ içermesi, sahip olduğu özel aromasının yanı sıra gevrek tekstürü nedeniyle çerez olarak tüketiminin yanı sıra başta çikolata endüstrisi olmak üzere şekerleme ve pastacılık alanlarında yoğun olarak kullanılmaktadır (Karaosmanoğlu ve Üstün, 2019).

Gıda güvenliği, halk sağlığını ve ekonomik sürdürülebilirliği korumada kritik bir unsurdur. Fındık gibi tarımsal ürünlerin işlenmesinde ortaya çıkabilecek kimyasal ve biyolojik tehlikeler, tüketici sağlığını doğrudan tehdit etmektedir. Afla toksin kontaminasyonu, hijyen eksiklikleri ve yetersiz depolama koşulları hem halk sağlığı hem de ihracat potansiyeli açısından önemli riskler oluşturmaktadır. Gıda kaynaklı hastalıklardan kaynaklanan üretkenlik kaybı ve tıbbi harcamalar, ekonomik değeri yüksek olan fındık ihracatını da olumsuz etkileyebilir (Jaffee et al., 2018).

Fındık ürünleri, üretimden tüketime kadar geçen süreçte biyolojik, kimyasal ve fiziksel risklere açık bir gıda grubudur. Özellikle afla toksin kontaminasyonu, kimyasal kalıntılar ve mikrobiyolojik tehditler, tüketici güvenini sarsabilir ve uluslararası pazarlarda ciddi sorunlara yol açabilir (Karaosmanoglu, 2023b; Chen et al., 2023). Bu nedenle, fındık işletmelerinde gıda güvenliğinin sağlanması yalnızca halk sağlığı açısından değil, aynı zamanda ekonomik sürdürülebilirlik ve ticari başarı açısından da hayati bir gerekliliktir.

Gıda güvenliği konusunda yapılan araştırmalar genellikle üretim veya tüketim aşamalarına odaklanmakta, ancak işleme, taşıma ve depolama gibi kritik ara aşamalar yeterince değerlendirilmemektedir (Reardon, 2015). Bu süreçlerin kontrol altına alınması hem kalite korunumu hem de ihracat başarı şansı açısından belirleyici bir rol oynamaktadır. Bu bağlamda, risk temelli yaklaşımlarla desteklenen entegre gıda güvenliği yönetim sistemlerinin uygulanması kaçınılmazdır (Food Standards Agency et al., 2020).

HACCP gibi yönetim sistemleri, risk değerlendirmesi sonucunda fındık üretim ve işleme süreçlerindeki kritik kontrol noktalarını belirlemeye ve bu noktalarda gerekli önlemleri almaya olanak tanır. Böylece afla toksin kontaminasyonu veya kimyasal kirleticiler gibi potansiyel tehlikeler, erken tespit edilip kontrol altına alınabilir (Sartoni et al., 2025).

Fındık işletmelerinde bu sistemlerin etkinliği, sektöre özgü ön koşul programlarının ve HACCP ilkelerine dayalı yapıların benimsenmesiyle artırılabilir. Aynı zamanda bu sistemlerin sürdürülebilirliği, işletme ölçeği, çalışan eğitimi, teknolojik altyapı ve izleme rutinlerinin kalitesi gibi faktörlerden etkilenmektedir (Nguyen & Li, 2022).

Sonuç olarak, fındık işletmelerinde gıda güvenliği, yalnızca hijyen kurallarıyla sınırlı kalmamalı; mevzuat uyumu, risk yönetimi ve teknolojik uygulamalarla desteklenmelidir. Bu çalışma, fındık işletmelerinde gıda güvenliği yönetim sistemlerinin önemi, karşılaşılan riskler ve çözüm önerileri üzerine kapsamlı bir değerlendirme sunmayı amaçlamaktadır (Matthews, 2014; Panghal et al., 2018).

Fındık İşletmelerinde Gıda Güvenliği Yaklaşımı

Fındık sektörü, üretimden tüketiciye uzanan tedarik zinciri boyunca çok sayıda güvenlik riskine maruz kalmaktadır. Bu riskler; biyolojik (mikroorganizma kontaminasyonu), kimyasal (pestisit kalıntıları, afla toksinler) ve fiziksel (yabancı maddeler) olarak sınıflandırılabilir. Bu tür tehditlerin kontrol altına alınabilmesi için sistematik ve bilimsel temellere dayanan bir gıda güvenliği yönetimi gereklidir.

Tehlike Analizi ve Kritik Kontrol Noktaları (HACCP) sistemi, fındık işletmelerinde uygulanabilecek en etkili önleyici kontrol mekanizmalarından biridir. Bu sistem, tüm gıda işleme süreci boyunca kritik kontrol noktalarının belirlenmesine, bu noktalarda tehlikelerin tanımlanmasına ve kontrol önlemlerinin uygulanmasına imkân tanır (Motarjemi & Lelieveld, 2014). HACCP, nihai ürün analizine dayalı geleneksel yöntemlerin aksine, riskleri ortaya çıkmadan önce önlemeye odaklanır.

Ancak yalnızca HACCP'in uygulanması yeterli değildir. Günümüzde giderek daha fazla işletme, tüm tedarik zincirini kapsayan entegre gıda güvenliği yönetim sistemlerine yönelmektedir. Bu kapsamda ISO 22000 standardı öne çıkmaktadır. ISO 22000, HACCP'i de içinde barındıran, risk temelli düşünceye dayalı ve organizasyonel bağlama uygunluk sağlayan bir çerçeve sunar (Başaran, 2016).

ISO 22000'in sunduğu sistematik yapı sayesinde, gıda güvenliği yönetimi yalnızca üretim aşamasında değil, aynı zamanda taşıma, depolama ve dağıtım gibi zincirin tüm aşamalarında kontrol altına alınabilir. Bu durum, fındık gibi hassas ürünlerin güvenliğini sağlamada büyük avantaj sunar. Ayrıca, ISO 22000 standardı, iç ve dış iletişim mekanizmalarının güçlendirilmesi, sürekli iyileştirme süreçlerinin işletilmesi ve izlenebilirlik gibi konularda da işletmelere değer katar (WCS, 2017).

Bununla birlikte, fındık işletmelerinin HACCP ve ISO 22000 sistemlerini benimsemesi; sadece belge sahibi olmakla sınırlı kalmamalı, aynı zamanda sistemlerin gerektirdiği eğitim, denetim, ekipman uygunluğu ve kurumsal kültürün oluşturulması gibi gereklilikler de yerine getirilmelidir. Aksi takdirde, bu sistemlerin uygulamada etkinliği sınırlı (Öztürk & Arıcı, 2019).

Sonuç olarak, fındık işletmelerinde etkin bir gıda güvenliği yaklaşımı için yalnızca mevzuatlara uyum değil; aynı zamanda eğitim, teknoloji kullanımı, proses takibi ve kurumsal farkındalık da temel unsurlar olarak değerlendirilmelidir.

Risk Faktörleri ve Tehditler

Fındık işletmeleri, üretimden tüketime kadar olan süreçte birçok risk faktörüyle karşı karşıya kalmaktadır. Bu riskler genel olarak mikrobiyolojik, kimyasal ve fiziksel kontaminasyonlar şeklinde sınıflandırılabilir. Her bir risk grubu hem ürün kalitesi hem de tüketici sağlığı üzerinde doğrudan tehdit oluşturmaktadır.

Mikrobiyolojik Riskler

Fındık ürünleri, özellikle hijyen eksikliklerinin bulunduğu işletmelerde Salmonella, Listeria ve E. coli gibi patojenlerle kontamine olabilmektedir. Bu mikroorganizmalar; uygun olmayan personel hijyeni, kirli ekipman kullanımı ve yetersiz sanitasyon uygulamaları sonucu gıdaya bulaşmaktadır (Vaillant et al., 2005). Ayrıca, bu bakteriler termal işleme dayanıklı olup uzun raf ömrü boyunca canlı kalabilmektedir. Dünya genelinde gıda zehirlenmelerinin %90'ından fazlasının mikrobiyal kontaminasyondan kaynaklandığı bilinmektedir (Fung et al., 2018). Bu nedenle fındık işletmelerinde düzenli mikrobiyolojik analizler, hijyen protokolleri ve sanitasyon programları zorunludur.

Kimyasal Güvenlik Riskleri

Kimyasal kirlenme, fındık işletmeleri açısından ciddi sağlık ve ticari sonuçlar doğurabilecek bir diğer önemli tehlikedir. Tarım ilaçları kalıntıları, ağır metaller (kurşun, arsenik, kadmiyum, cıva vb.) ve proses ekipmanlarından sızan maddeler, ürünlerin kimyasal güvenliğini tehdit etmektedir (Fung et al., 2018). Özellikle afla toksinler, Aspergillus flavus ve Aspergillus parasiticus türü mantarlar tarafından üretilen, kansorejen etkiye sahip toksinlerdir ve fındıkta en yaygın görülen kimyasal risk faktörüdür (Siciliano et al., 2016). Afla toksinler, termal işlemlerde parçalanmaz ve ürünün raf ömrü boyunca stabil kalabilir. Bu nedenle, üretimin her aşamasında kimyasal risk yönetimi büyük önem taşımaktadır.

Fiziksel Tehlikeler

Fındıkların işlenmesi ve paketlenmesi sırasında cam, metal, taş, plastik parçacıkları gibi fiziksel kontaminantların ürüne karışması, tüketici açısından önemli bir sağlık riski yaratmaktadır. Bu tür bulaşmalar genellikle ekipman arızaları, zayıf kalite kontrol sistemleri ya da yetersiz eğitimli personel kaynaklıdır. Fiziksel risklerin kontrolü için metal dedektörleri, optik ayırıcılar ve etkili kalite güvence sistemlerinin kullanımı gereklidir (Frank et al., 2011).
Tüm bu risk faktörleri, fındık ürünlerinin iç ve dış pazarda güvenilirliğini doğrudan etkileyen unsurlardır. Bu nedenle, işletmelerin üretim zinciri boyunca etkili bir izleme ve kontrol sistemi oluşturması elzemdir (Silver & Bassett, 2008).

Depolama, Taşıma ve İşleme Koşulları

Fındık ürünlerinin kalitesi ve güvenliği, yalnızca üretim aşamasında değil, aynı zamanda depolama, taşıma ve işleme koşullarında da belirlenmektedir. Hasat sonrası süreçlerde uygulanan yöntemlerin yetersizliği, ürünlerde mikrobiyolojik ve kimyasal kontaminasyon riskini artırarak gıda güvenliğini tehdit eder hale getirebilir (Silvestri et al., 2021).
Depolama koşulları, özellikle afla toksin oluşumunu etkileyen temel faktörlerden biridir. Afla toksin üreten mantarlar, sıcak ve nemli ortamlarda kolaylıkla çoğalabildiğinden dolayı, fındıkların düşük sıcaklıkta ve %60'tan az bağıl nem seviyesinde saklanması önerilmektedir. Bu parametrelerin kontrol altında tutulması hem raf ömrünü uzatmakta hem de toksik maddelerin oluşumunu sınırlandırmaktadır (Mencarelli et al., 2008).
Ayrıca, inert atmosfer teknikleri (örneğin; azot- N_2 veya karbondioksit- CO_2 ile doyurulmuş ortamlar), oksijenin depolama alanlarından uzaklaştırılmasını sağlayarak kimyasal oksidasyonu azaltır. Bu yöntem, özellikle lipid oksidasyonu ve renk bozulmalarını önlemede etkin bir rol oynar. Böylelikle ürünün besin değeri ve duyusal özellikleri korunabilir (Yurttas et al., 2000).
Taşıma süreci de gıda güvenliğini etkileyen önemli bir halkadır. Uygun olmayan taşıma araçları, hijyenik olmayan yüzeylerle temas, aşırı sıcaklık ve nem gibi çevresel faktörler, fındığın güvenliğini riske atmaktadır. Bu noktada, taşıma araçlarının düzenli dezenfekte edilmesi ve sıcaklık-nem izleme sistemleri ile donatılması önerilmektedir (Ghirardello et al., 2014).
İşleme alanlarında hijyen, sadece ürün kalitesini değil, aynı zamanda çalışan sağlığını da doğrudan etkileyen bir unsurdur. Gıda ile temas eden ekipmanların yüzey temizliği, iş elbiseleri, kişisel hijyen ve çevresel hijyen gibi faktörler bir bütün olarak değerlendirilmelidir. Üç kritik bölge olan gıda bölgesi, sıçrama bölgesi ve gıda dışı bölge, temizlik ve dezenfeksiyon açısından farklı stratejilerle ele alınmalı ve düzenli kontrol edilmelidir (Covolan, 2024).
Sonuç olarak, fındık işletmelerinde yalnızca üretim süreçlerinin değil; depolama, taşıma ve işleme süreçlerinin de bilimsel ilkelere uygun olarak yönetilmesi, gıda güvenliğinin sürdürülebilirliği açısından vazgeçilmezdir.

Gıda Güvenliği Sistemlerinin Etkinliği ve Uygulanabilirliği

Fındık işletmelerinde gıda güvenliği sistemlerinin etkin bir şekilde uygulanabilmesi, yalnızca teknik altyapıya değil, aynı zamanda organizasyonel kapasiteye, çalışan eğitimi düzeyine ve yönetim anlayışına da bağlıdır. Özellikle küçük ve orta ölçekli işletmeler (KOBİ'ler), bu sistemleri uygulama konusunda çeşitli zorluklarla (Mensah & Julien, 2011).

HACCP ve ISO 22000 gibi sistemlerin etkili olması için, yalnızca teknik dökümantasyon yeterli değildir. Bu sistemlerin başarıyla sürdürülebilmesi; personelin farkındalık düzeyi, yönetim desteği, düzenli iç denetimler ve sürekli iyileştirme döngüsünün varlığı gibi birçok faktörü bir arada gerektirir. Bu bağlamda, işletmelerde gıda güvenliği kültürü oluşturulması büyük önem taşımaktadır (Nguyen & Li, 2022).

Özellikle HACCP sisteminin işlevsel hâle gelebilmesi için ön koşul programlarının (örneğin: temizlik ve sanitasyon programları, haşere kontrolü, ekipman kalibrasyonu) sistematik biçimde işletilmesi gerekir. Ön koşulların eksik olduğu durumlarda, HACCP'in etkili çalışması mümkün değildir.

Gıda Güvenliği Yönetim Sistemlerinin mevcut performansını değerlendirmek amacıyla teşhis araçları, iyileştirme matrisleri ve seçim kılavuzları gibi araçlar geliştirilmiştir. Jacxsens ve arkadaşlarının (2010) geliştirdiği teşhis modeli, işletmelerin bağlam durumu, kontrol faaliyetleri ve çıktı performansı gibi bileşenleri analiz ederek güçlü ve zayıf yönlerin belirlenmesini sağlamaktadır. Bu analizler sayesinde, işletmeler kısa, orta ve uzun vadeli geliştirme planları oluşturabilir (Luning et al., 2008; Luning et al., 2011).

Ayrıca, Mikrobiyal Değerlendirme Şeması (MAS) gibi protokollerle yapılan değerlendirmeler, gıda güvenliği performansının ölçülmesine katkı sağlamaktadır. MAS, mikrobiyolojik verilerin sistematik şekilde analiz edilmesini ve potansiyel darboğazların tanımlanmasını kolaylaştırır (Jacxsens et al., 2010).

Bu sistemlerin sürdürülebilirliği açısından, devlet desteklerinin ve uluslararası proje fonlarının özellikle KOBİ'lere yönelik olarak artırılması önemlidir. Gıda güvenliği düzenlemelerinin yerel düzeyde uygulanabilir hâle getirilmesi, sektörel katılımı artıracak ve sistemlerin sahada işlerliğini kolaylaştıracaktır.

Kısacası, fındık işletmelerinde gıda güvenliği sistemlerinin etkinliği yalnızca teknik bilgiye değil; aynı zamanda bütüncül, sürekli geliştirilebilir ve işletmeye özgü uyarlanabilir bir yaklaşım gerektirir.

Sonuç ve Öneriler

Fındık işletmelerinde gıda güvenliği; üretim, işleme, depolama ve dağıtım süreçlerinin tamamını kapsayan bütüncül bir yaklaşım gerektirmektedir. Afla toksin kontaminasyonu, mikrobiyolojik ve kimyasal riskler ile hijyen eksiklikleri, sektörde karşılaşılan başlıca sorunlar arasında yer almaktadır. Bu sorunların kontrol altına alınabilmesi için HACCP ve ISO 22000 gibi sistemlerin etkili biçimde uygulanması büyük önem taşımaktadır.

Fındık işletmelerinde modern depolama koşulları, inert atmosfer uygulamaları, mikrobiyolojik test protokolleri ve çalışan hijyenine yönelik eğitimler, gıda güvenliği sistemlerinin başarısını doğrudan etkilemektedir. Aynı zamanda, teşhis ve değerlendirme araçlarının kullanımı, işletmelerin güçlü ve zayıf yönlerini görmelerine yardımcı olmakta; sürekli iyileştirme anlayışını desteklemektedir.

- Gıda güvenliği sistemlerinin (HACCP, ISO 22000) uygulanması teşvik edilmeli ve zorunlu hâle getirilmelidir.
- Depolama, işleme ve taşıma süreçlerinde sıcaklık ve nem kontrolü sağlanmalı, inert atmosfer teknolojileri yaygınlaştırılmalıdır.
- Tarım kimyasalları ve proses ekipmanları düzenli analizlerle denetlenmelidir.
- Çalışanlara yönelik hijyen ve sanitasyon eğitimleri periyodik olarak düzenlenmelidir.
- KOBİ'ler için teknik destek ve finansal teşvik programları geliştirilmeli, mevzuat yerel ölçeklere uyarlanmalıdır.

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Fermented Foods and Human Health

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Abstract

Humans need nutrients to survive, essential for good health and strength of the body. However, current biological, social and psychological practices greatly affect people's dietary intake, leading to health-related problems. Situation which forces individuals to take drugs and supplements, with many undesirable secondary effects. In this way, scientists investigate uncountable strategies to solve these complications, and one of the alternatives is fermented foods. About 30% of the human diet consists of fermented foods, consumed in most societies with different cultures and lifestyles. They are cost-effective due to their preparation using available seasonal raw materials from local farming. This type of alimentation, widely distributed, was adopted for thousands of years for its organoleptic and mainly preservative characteristics. The fermentation gives specific sensory proprieties and prolongs shelf life/safety depending on the products and fermenting microorganisms. The most studied category of fermented foods is dairy products. Nowadays, their consumption is motivated by health-related prospects. Increasing evidence of the association of fermented foods with health has further increased their popularity in recent years. Fermented foods are a source of biotics (probiotics, prebiotics, synbiotics, postbiotics and parabiotics), related to various health benefits, from the digestive (assimilation, microbiota equilibrium…) to the immune system modulation. Differences in the microbial consortia present or used have various health effects. Several studies evaluated their anti-inflammatory, anti-microbial, anti-diabetic, anti-oxidative and other effects induced by beneficial components produced during fermentation processes. The adoption of fermentation technology is in progress and many start-ups are created in the West.

Key Words: *Functional Foods, Fermentation, Diet, Biotics, Health.*

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Determinants of Poverty Among Rural Farming Households in Ganye Local Government Area of Adamawa State, Nigeria

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Abstract

Poverty is one of the difficult problems that affect rural farming households in Nigeria because farming is their primary source of income. In Ganye Local Government Area of Adamawa State, Nigeria, the study examined the causes of poverty among rural agricultural households. The particular research objectives were to define the socioeconomic characteristics of the respondents, determine their level of poverty, and investigate the reasons that cause poverty among the respondents. The primary data for the investigations came from 250 respondents who were selected using a multi-stage random selection technique. The analytical techniques used were descriptive analysis, Foster-Greer-Thorbeeke (FGT) and Logit regression model. The study's findings revealed that the majority of rural farming households' heads were men (84.40%), married (85.60%), with a mean age of 41.25 years, educated (84.00%), and with a mean farm size of 2.56 ha and a mean household size of 7 individuals. However, the majority of responders (87.60%) lacked access to credit. The distribution of respondents by level of poverty (P_o, P_1, and P_2) according to the study's findings was also discovered to be 0.60 for incidence, 0.31 for depth, and 0.19 for severity. The Logit regression model's findings demonstrated that while age, marital status, and household size had adverse effects on poverty status among farming households and were statistically significant at different levels, sex, formal education, primary occupation, access to credit, total income, and annual remittances had favorable effects. The study's conclusions recommended that rural farming households have access to centers for skill development, that adequate financing be provided for the development of infrastructure, and that credit facilities be accessible. These suggestions would contribute to reducing poverty.

Key Words: *Determinants, Poverty status, Rural farming household, Logit regression model and Adamawa State*

Introduction

Poverty is widely recognized as a significant indicator of underdevelopment, with its reduction often equated with progress in development or economic advancement. It is a social state characterized by inadequate access to necessities of life (food and non-food) to maintain a minimal level of living that is socially acceptable in a particular society. Ample food, a place to live, access to potable water, health care, education, and employment opportunities are a few of these fundamental well-being determinants. Since most of these facilities are essentially controlled by the market, who possesses what always depends on an individual's income or other disposable resources that are available to households or individuals (Mansi et al., 2020, Henry et al., 2023).. According to Ike and Uzokwe (2015), poverty is defined as a household or individual not having enough income to meet these demands at the bare minimum levels in the society in question. It goes without saying that poverty is a global issue, yet the threat of poverty is most destructive in the developing world. Particularly over the past ten years, the majority of developing countries' human conditions have drastically worsened, real disposable income has significantly decreased, and rates of hunger have increased. The quantity and quality of health have drastically declined, and food production has barely kept up with population growth (Waseem et al. 2020). The extent of poverty among farmworkers and farmers is influenced by the larger society in which they reside. Low levels of assets combined with poor returns lead to poverty. Only their own labor, which is invariably used in laborious, physically taxing, low-paying employment, makes up the majority of the poor's possessions. Poverty perpetuates itself. There is a great likelihood that a poor person or family will remain poor. High disease risks, mobility restrictions, and restricted access to education are all associated with low earnings (Adekoya, 2014).

According to Hagan (2018), poverty results from a lack of assets and low returns. Only their own labor, which is invariably used in laborious, physically taxing, low-paying employment, makes up the majority of the poor's possessions. Poverty perpetuates itself. There is a great likelihood that a poor person or family will remain poor. High disease risks, mobility restrictions, and restricted access to education are all associated with low incomes. When one or more people fall short of the standard of living that is considered to be a fair minimum in terms of economic welfare, whether in an absolute sense or by the standards of a particular society, they are said to be living in poverty (Jude et al., 2020). The prevalence of poverty is rising, along with its consequences for the country as a whole and the rural population in particular. One in five people on the planet are said to be living in abject

poverty. According to Mood and Jonsson (2016), poverty is the inability to effectively meet needs for things like food, shelter, clothes, and Medicare. It is also a condition in which a person, family, community, or country may find themselves lacking in basic necessities. It is a widely multifaceted, partially subjective phenomenon that is frequently seen as both the root of underdevelopment and one of its symptoms. It takes various forms, one of which is the inability of an individual or group to contribute to and thrive in society.

As of 2022, a staggering 712 million people worldwide were living in extreme poverty (defined as less than $2.15 per day, based on the international poverty line). According to the World Bank (2024), extreme poverty continues to be concentrated in regions of Sub-Saharan Africa, areas affected by conflict and fragility, and rural settings. The report emphasizes that addressing poverty comprehensively necessitates addressing its multifaceted dimensions. Furthermore, it highlights that countries cannot effectively combat poverty without simultaneously enhancing the overall well-being of their populations, including through equitable access to healthcare, education, basic infrastructure, and services, as well as digital technologies. Rural poverty is a significant issue globally, with nearly 63 percent of poverty concentrated in rural areas (UN, 2024).

In 2018 over 62.32 million people live in extreme poverty in Nigeria representing about 30.90% of the population (World Bank, 2022). According to the National Bureau of Statistics (NBS, 2020), location and education both have a significant impact on poverty. In Nigeria, poverty is mostly perceived as a rural issue because the majority of residents depend on agriculture for a living. According to IFAD (2007), poverty in Nigeria is generally evenly distributed throughout the nation, but it is particularly bad in some regions, such as the desert northern region bordering Niger. Rural areas have a particularly high level of poverty since there are few or no social services and little infrastructure. Farm and non-farm activities are becoming increasingly important, but little is known about how they fit into rural households' income generating plans in emerging nations like Nigeria (Ibekwe, Onyemawa, Henri-Ukoha, Korie & Nwaiwu, 2010). Even though it is common knowledge that rural households have a propensity to work several jobs, it is important to systematically relate livelihood diversification to programs aimed at reducing rural poverty and ensuring food security.

Statement of the problem

Although poverty is a global problem, its consequences are particularly noticeable in rural South East Asia and sub-Saharan Africa (Uchechi & Okewale 2010). Despite being endowed with natural resources, Nigeria, one of sub-Saharan Africa, continues to experience widespread poverty. This is accurate when one considers that, according to Iheke (2010), 35% of Nigerians live in absolute poverty, with over 70% of the population being categorized as poor. According to Igbuzor (2006), poverty is defined as the inability of a person to obtain basic requirements of life or to live on less than $1 per day. According to Obadan (2001), poverty has numerous manifestations and aspects, including living in unsanitary neighborhoods, being over-indebted, being dependent on money, being unable to exercise one's independence, and being unable to meet one's fundamental requirements. These exert pressure on the physical environment, contributing to the deterioration of the environment.

The effects of poverty on rural households are troubling because these households are more vulnerable to adverse changes in the political, social, economic, and environmental factors that worsen their poverty. Federal Office of Statistics (FOS, 2011) and Iheke (2010) list these factors as being worsened food insecurity, risk-averse behavior to protect the meager resources at hand, low income due to subpar social amenities, and unfavorable government policies. Because rural households are particularly vulnerable to poverty, it is necessary to start programs that will increase their sources of income in order to reduce their poverty. The majority of people in sub-Saharan Africa's rural areas make their living primarily from agriculture, so it is crucial to increase agricultural productivity through the use of advanced technology as well as their capacity to market and distribute their goods in order to increase their income (Uchechi & Okewale 2010). In Nigeria, the poverty headcount rate in 2019 was 40.09%, or 40.1 percent of the country's population. While the squared poverty gap index (severity) is 5.63 and the poverty gap index is 12.85%. In Adamawa state, the poverty headcount was 75.4%1, the poverty gap index was 27.64%, and the squared poverty gap index (severity) was 13.21%; poor families are headed by 82.6% women and 70.9% men, respectively (NBS, 2019).

Objective of the Study

i. describe the socio-economic characteristics of the respondents
ii. determine the poverty status of the respondents in the study area,
iii. examine the determinants of poverty among the respondents

Materials and Methods

Study Area

The study was carried out in Ganye local government areas of Adamawa State (Fig. 1). Ganye local government areas lies between latitude 8º12’- 8º40’North and longitude 11º37’-12º15’ East. It is bounded by Jada to the north, Mayo-belwa to the northwest, Toungo to the south, Taraba state to the west and Cameroon Republic to the east.

Ganye has a land mass of 2,011.47 km2 and a projected population of 240,686. The mean annual temperature of the study area for maximum is 32.3ºC and minimum 19.6ºC while the average annual rainfall total is 1,231 mm with a distinct dry season which begins in November and ends April and the wet season begins in April and ends in October or sometimes in November. The areas are located within the Guinea Savannah zone of the Nigeria's vegetation zones. The major economic activity in the area is agriculture. Food crops grown in the area are maize, sorghum, cowpea, cassava and potatoes. While cash crops such as groundnuts, rice, yam and sugarcane are produced in large quantities. Major livestock reared in the zone are cattle, sheep and goats (Adebayo and Zemba, 2020; Akosim et al., 2020; Kadams et al., 2020; Zemba et al., 2020).

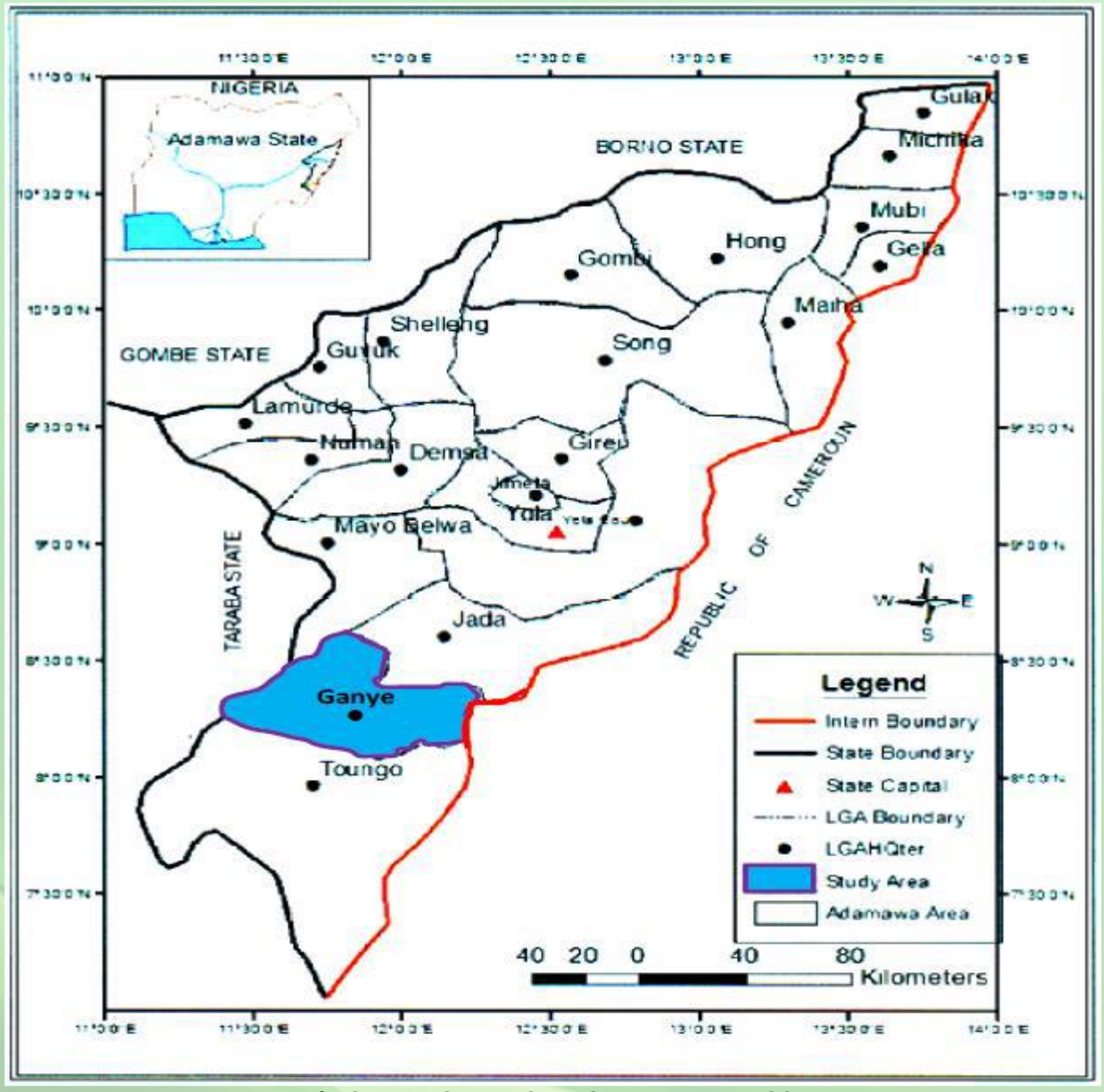


Fig 1:Map of Adamawa Showing the study Area Source: Adebayo, 2020

Sampling procedure and Sampling Size

A multi stage sampling technique was used to collect primary data from 250 rural farming households in the study area using questionnaire, selected from fifteen farming communities namely Santasa, Sangasumi, Sanyigmi, Gamu, Dalebbi, Dimgam, Gurum, Gurum-Novan, Jangani, Kwana-doya, Yebbi, Sugu, Jagg, timdore and Dabirra respectively. The respondents were randomly selected from each community proportionate to the number of the household in each community.

Method of Data Collection

Primary data was gathered from rural homes in the study area using a structured questionnaire and interview schedule.

Analytical Technique

Both descriptive and inferential statistics were used to achieve the research objectives of the study. Descriptive statistics was used to describe the socioeconomic characteristics of the respondents while inferential statistics such as Foster, Greer and Thorbecke (FGT) poverty model to determine their poverty status and Logit regression model was used to determine theeffect of some socio-economic characteristics on poverty.

Foster, Greer and Thorbecke (FGT)Poverty model

One of the methods that was used in the study is the popular FGT measures of poverty. This was used to determine the Poverty Status of the farming households in the study area. The poverty status of the farmers was measured based on their consumption/expenditure from the sources of their livelihood. The consumption/expenditure level that separates the poor from the rest of the population is called the poverty line. The poverty line helps us in classifying the poor and non-poor and then calculates the poverty indices for rural households in the study area. The first step in calculating the consumption/expenditure based index is to assess a level of consumption/expenditure below which an individual is defined as poor: the so-called poverty line. It is well known that if consumption/expenditure is divided into two categories, food consumption/expenditure and non-food consumption/expenditure, the poorer people are, the higher the proportion of their overall expenditure that is accounted for by food consumption/expenditure. In determining consumption/expenditure levels that can be used to separate the poor from the non-poor, food consumption/expenditure is the most significant measure. Thus a food poverty line (a minimum level of food consumption/expenditure) is first calculated. A non-food minimum allowance is then calculated and added to the food poverty line to provide the total poverty line. This poverty line was used to determine the magnitude and intensity of poverty among the farming household in the study area.

The Foster-Greer-Thorbeeke (FGT, 1984) indices was used to measure the magnitude, depth and severity of poverty. The P_α class of poverty according to Foster *et al.* (1984) can be addressed in respect of poverty incidence, ($\alpha = 0$); depth of poverty ($\alpha = 1$); and severity of poverty ($\alpha = 2$), the higher the value of α, the greater the weight given to the severity of poverty. For $\alpha = 0$, FGT reduces to headcount ratio (H) and when $\alpha = 1$, it reduces to poverty gap and if $\alpha = 2$, we have poverty severity index.

Following Greene (2003) as well as Adigun, Bamiro & Adedeji (2015) general class of a poverty measure which combines these three characteristics of poverty can be written as:

$$P_\alpha(y,z) = \frac{1}{n}\sum_{i=1}^{q}\left(\frac{z-y_i}{z}\right)^\alpha \quad (1)$$

Where:

n = Total number of households in a population

q = The number of poor households

z = The poverty line (Naira)

y_i = Household per capita expenditure (Naira)

α = Poverty aversion parameter and takes values, 0, 1, 2

$\left(\frac{z-y_i}{z}\right)$ = Proportionate shortfall in income below the poverty line

α takes on the value 0, 1, 2, to determine the type of poverty index.

When $\alpha = 0$, the expression reduces to

$$P_o = \left(\frac{1}{n}\right)q = \left(\frac{q}{n}\right) \quad (2)$$

Where:

P_o = poverty incidence

n = total number of households in a population

q = the number of poor households

This is referred to as the Headcount Ratio (poverty incidence) describing the proportion of the population that falls below the poverty line. This measure gives equal weight to all poor irrespective of the intensity of their poverty. The headcount ratio has been criticized for focusing only on the number of the poor being insensitive to the severity of poverty and changes below the poverty line. That is, it treats all the poor equally whereas not all the poor are

equally poor. Also, neither a transfer from the less poor to poorer, nor a poor person becoming poorer would register in the index, since the number of the poor would not have changed.
Where $\alpha = 1$, the expression in the equation (equation 1) reduces to:

$$P_1 = \frac{1}{n}\sum_{i=1}^{q}\left(\frac{z - y_i}{z}\right) \quad (3)$$

Where:
P_1 = poverty gap
n = total number of households in a population
q = the number of poor households
z = the poverty line (Naira)
y_i = expenditure of the poor household less than the poverty line (Naira)
And this is called Poverty Gap (depth of poverty) each poor is weighed by his or her distance from the poverty line, relative to z.
Where $\alpha = 2$, the expression now becomes

$$P_2 = \frac{1}{n}\sum_{i=1}^{q}\left(\frac{z - y_i}{z}\right)^2 \quad (4)$$

Where:
P_2 = poverty severity
n = total number of households in a population
q = the number of poor households
z = the poverty line (Naira)
y_i = expenditure of the poor household less than the poverty line (Naira)
Equation (4) is called poverty severity index. In this measure, the weight given to each poor is proportional to the square of his or her income shortfall from the poverty line. This index weighs the poverty of the poorest individual more heavily than those just slightly below poverty line. This measure all the three indicators of the poverty stated above.

Binary Logit Model
The Binary Logit (BNL) Model was employed in this study. In this model, the data on the dependent variable (poverty status) is bi-variate, that is, poor or non-poor. The BNL model was therefore, employed due to the nature of the decision variable. For such a dichotomous outcome, the BNL model is the most appropriate analytical tool (Pur et al. 2016; Benedicta et al. 2010; Kristof, 2009). The implicit form of the model is expressed as:

$$Y = \ln\left(\frac{\emptyset_1}{1-\emptyset_1}\right) = \beta_o + \sum_{j=1}^{k}\beta_j X_{ij} + \varepsilon_i \quad (5)$$

Where:
Y = Dependent variable (i.e, the binary variable; Y = 1 for a household that diversified livelihood activities and Y = 0 for otherwise.
β_o Intercept
β_i = Estimated parameters
X_i = Explanatory variables
i = 1, 2, 3, ------ n number of explanatory variables
ε_i = the matrix of unobserved random effects, $\frac{\emptyset_i}{1-\emptyset_i}$ is "odd", and $ln\left(\frac{\emptyset_i}{1-\emptyset_i}\right)$ is the logarithm of "odds".
Equation (5) can be manipulated to give the odds ratio using equation (6):

$$\frac{\emptyset_i}{1-\emptyset_i} = \exp\left(\beta_0 + \sum_{i=1}^{k}\beta_i X_i\right) \quad (6)$$

The probability of the extent of access was calculated using equation (7):

$$\emptyset_i = \frac{exp\left(\beta_0 + \sum_{i=1}^{k}\beta_j X_{ij}\right)}{1 + exp\left(\beta_0 + \sum_{i=1}^{k}\beta_j X_{ij}\right)} \quad (7)$$

Equation (11) is intrinsically linear since the logit is linear in X_i (Gujarati, 2004); it indicates that probability $\emptyset_i$lies between zero and one and vary non-linearly with X_i. The equation for calculating partial effects of continuous variable is denoted by:

$$\frac{\partial \emptyset_i}{\partial x_i} = \emptyset_i(1-\emptyset)\beta_j \quad (8)$$

The partial effects of the discrete variables will be calculated by taking the difference of the mean probabilities estimated for the respective discrete variable, X_i = 0 and X_i = 1.
The marginal effects measure the expected change in probability of a particular choice being made with respect to a unit change in an explanatory variable (Greene, 2003).

$$Y = \ln\left(\frac{\emptyset_1}{1-\emptyset_1}\right) = \beta_o + \sum_{j=1}^{k} + \beta_1 X_1 + \beta_2 X_2 \ldots\ldots + \beta_{10} X_{10} + \varepsilon_i \quad (9)$$

Y = Dependent variable (i.e, the binary variable; Y = 1 for poor and Y = 0 for non-poor.
The independent variables were defined as follows:

Table 1. Exogenous variables in the binary logit regression to test poverty status

Variable	Measurement	Expected sign
Age (X_1)	In years	±
Sex (X_2)	Binary variable (1=male, 0=otherwise	+
Marital Status (X_3)	Binary variable (1=married, 0 = otherwise)	+
Households Size (X_4)	Number	+
Formal Education (X_5)	Years	±
Primary Occupation (X_6)	Binary (1 = farming, 0 = otherwise)	±
Access to Credit (X_7)	Binary (1= yes, 0 = No)	±
Total Annual Income (X_8)	Naira	+
Annual remittances(X_9)	Naira	+

Results and Discussion

Socio-economic characteristics of the respondents

The socio-economic characteristics of the respondents here is presented in Table 1. Majority 82.80%) of the respondents are less than 50 years of age with the mean age of 41.25 years. The results showed that 89.18% of the household heads were male. The finding also agrees with Micheal et al. (2015) which revealed that there are more male-headed households in rural Nigeria than female-headed households. Majority (85.60%) of the respondents were married. This indicates that married people constitute bulk of household heads in the rural areas. This agrees with Igwe (2013) who reported that married people could imply larger household size with more mouths to feed. This could aggravate poverty. It also shows that majority (84.00%) of the respondents had one form of formal education or the other. The result revealed that majority of the respondents were literate and this can enhance the level of productivity. This agrees with the study conducted by Ume and Ochiake (2016) that education plays a vital role in formal orientation on dessimination of improved farm practices.

The result on household size reveals that, majority (41.20%) were between 6 – 10 people with a mean household of 7 people. This indication implies that a large household size means more responsibility to catter for the need of the family. The results indicate that75.20% of the respondents were engaged in farming as their primary occupation which include both arable cropping and rearing of livestock. This implies that major occupation of most of the household heads in the study area was farming. This finding corroborates with the finding by Odoh and Nwibo (2016) and Dia et al. (2023) who posited that most rural family in Nigeria are engaged in farming as their primary occupation.

The result shows that majority (82.80%) of the respondents had farm size between 1 – 3 hectares with mean farm size of the respondents is about 2.56 hectares. This is an indication that the farmers in the study area are small-scale farmers, hence food production will be in subsistence level. This finding corroborates with the finding o Fadipe at al. (2014) that majority of rural farmers in Nigeria are small-scale farmers who cultivate less than 5 hectares of land. The result indicates that 85.20% of the respondents had between 1 – 20 years farming experience. This indicates that the farming households' heads had farming experience that can help them improve their productivity on the farm by knowing the correct practices. It also revealed that 87.60% have no access to credit facilities. Their lack of access to credit facilities is as a result of them not being in any registered cooperative or farmers association. This study is in agreement with the study conducted by Sekumade and Osundare (2014) who posited that only few in the rural communities in Nigeria had access to credit.

Table 1. Socio-economic characteristics of the respondents (N=250)

Socio-economic characteristics	Frequency	Percentage
Age		
20 – 29	30	12.00
30 – 39	102	40.80
40 – 49	75	30.00
50 – 59	27	10.80
60 and above	16	6.40
Mean	41.25	
Sex		
Male	211	84.40
Female	39	15.60
Marital Status		
Married	214	85.60
Divorced	11	4.40
Widowed	25	10.00
Educational Level		
Non formal education	40	16.00
Primary education	101	40.40
Secondary education	87	34.80
Tertiary education	22	8.80
Household Size		
1 – 5	86	34.40
6 – 10	103	41.20
11 – 15	35	14.00
16 – 20	17	6.80
21 and above	9	3.60
Mean	7	
Primary Occupation		
Farming	188	75.20
Civil servant	43	17.20
Business	19	7.60
Farm Size (Ha)		
<1	8	3.20
1 – 3	207	82.80
4 – 6	35	14.00
Mean	2.56	
Farming Experience		
1 – 10	79	31.60
11 – 20	134	53,60
21 – 30	37	14.80
Access to Credit		
Yes	31	12.40
No	219	87.60

Source: Field Survey 2024

Assessing the Level of Poverty among Rural Farming Households

Analysis of Expenditure of Respondents and Determination of poverty line

The Foster-Greer-Thorbeeke (FGT) class of poverty measures was employed to estimate the poverty status of the rural farming households in the study area. Following the adoption of Foster, Greer and Thorbeeke measures the households' total expenditure was used to determine the households' poverty status. The result presented in Table 2 shows the household food and non-food expenditure, total expenditure, per capita expenditure, mean per capita expenditure and poverty line. The poverty line was constructed as two-third of the mean per capita household expenditure of all households. This approach has been used by many researchers and institutions (Oyakhilomen & Kehinde, 2016; NBS, 2020). Households were then classified into their poverty status based on the poverty line.

Hence, non-poor households were those whose per capita expenditure was above or equal to two-third of the mean per capita expenditure (poverty line) of all households while those households whose per capita expenditure were below two-third of the mean per capita expenditure were classified as poor. Based on this, the poverty line constructed as two-third of the mean per capita expenditure of all the households was N111,032.98. This implies that households whose annual per capita expenditure fell below N111,032.98 were classified as poor while households whose per capita expenditure equalled or above the poverty line was classified as non-poor.

Table 2. Analysis of Expenditure of Respondents and Determination of Poverty Line

Item	Amount (N / Annum)
Household Food Expenditure	69,362,195.00
Household Non-food Expenditure	53,208,640.00
Total Household Expenditure	122, 570, 835.00
Per Capita Household Expenditure $= \frac{Total\ household\ Expenditure}{Number\ of\ household\ members}$	41,637,366.50
Mean Per Capita Household Expenditure (MPCHE)	166,549.47
2/3 MPCHE (Poverty line)	111,032.98

Source: Field Survey, 2024

Poverty Indices of the Rural Farming Households

The values for the poverty measures the poverty incidence (P_o), Poverty gap index (P_1) and Poverty severity (P_2). From Table 3, a relative poverty line of N111,032.98 was established from the annual food and non-food expenditure of the rural farming households. This implies that a household having an average annual expenditure above the N111,032.98 was considered non-poor, those with average annual expenditure between N55,516.49 and N111,032.98 were considered moderately poor while those having annual average expenditure less than N55,516.49 were considered very poor. Thus the result of the poverty incidence (P_o) is 0.60 which indicate about 60% variability in the poverty of farming households were poor which means 62% of the farming household were not poor. That is out of the 250 rural farming households interview 151 of them were poor. This indicates that poverty was not predominant among the rural farming households which might be due to the fact that most of the household heads diversify their livelihood activities to earn more income to meet their daily needs.

The poverty gap index (P_1) results revealed was 0.31 indicating the gap between the poor and poverty line was 31%, therefore the poor will require 31% rise in their per capita expenditure to become non-poor which translate into N34,420.22 increament to the per capital expenditure of the poor. The poverty severity index (P_2) of the rural farming households was 0.19. This indicates that out of 151 poor households interview only 48 of that households were extremely poor. This implies that poverty is severe among poor farming households with about 19% of the farming households constitute the poorest among the respondents. In other words, the squared poverty gap takes into account not only the distance separating the poor from the poverty line, but also the inequality among the poor. The result is similar with the findings of Asogwa et al. (2012) who reported a poverty gap of 0.27 and poverty severity of 0.15 among farming households in Nigeria.

Determinants of Poverty among farming households in the Study Area

A Logit regression was employed to determine the determinants of poverty among farming households in the study area (Table 4). The usual regression diagnostics for the binary logistic regression models were computed to assess the fit of the individual observations. In this study, the result of the goodness of fit test shows that the overall goodness of fit is reflected in a non-significant of Pearson Chi-square p-value which is 0.9822. This implies that the data has a good-fit in explaining the relationship. The model adequacy test shows p-value for hat to be 0.000 which is highly significant and p-value for hatsq is 0.726 which is non-significant. The non-significant of hatsq suggest good model adequacy.

The result showed that The log likelihood function (-60.37) shows that the estimated model including a constant and the set of explanatory variables fit the data better. This implies a better relationship between odds ratio, probability of factors influencing poverty status (dependent variable) and the explanatory variables included in the model collectively contribute significantly to the explanation of farmers' influence in adopting a livelihood diversification strategy. R^2 (coefficient of determination) is 0.6047, suggesting that the model has a good fit to the data. This indicates that 60% of the variation in poverty in the study area is explained by variations in the specified explanatory variables on the changes in poverty among the respondents.

Table 3. Poverty Indices of the Respondents

Poverty Indices	Estimates
Mean Per Capita Household Expenditure	N166,549.47
2/3 Mean Per Capita Household Expenditure (Poverty line)	N111,032.98
1/3 Mean Per Capita Household Expenditure	N55,516.49
Poverty incidence (P_o)	0.60
Poverty depth (P_1)	0.31
Poverty severity (P_2)	0.19
Poor Households	60%
Non Poor Households	40%

Source: Field Survey, 2024

The results logit regression indicates that age (P<0,01), sex (P<0,05), marital status (P<0.10), household size (P<0.05), formal education (P<0.05), primary occupation (P<0.01), access to credit (P<0,05), annual income (P<0.05)) and annual remittances from children and relatives (P<0.01) significantly influence the probability that a household will be poor or non-poor.

The result of age of the household heads was found to have negative effect on the level of poverty and was significant at P<0.01 probability level with marginal effect of 0.8244273. This implies that a unit increase in age of household heads reducees their income by 82%. That is the older the respondents are more likely to become poor compare to their younger counterpart. This supports the theory put forth by Ola-fakuade et al. (2019), according to which the probability of poverty rises with the age of the household heads.

Sex had negative effect on level of poverty with marginal effect of 0.1077759 and was significant at P<0.05 level of probability. This implies that male household heads are 10% more likely to become poor compare to their female counterpart. Because most male household heads shoulder more responsibility than the female from both most culture or society.. This supports the findings of a study by Ike and Uzekwe (2015), which suggested that the majority of rural Nigerian women depend on their male counterparts for productive resources.

Marital status had negative effect on poverty and statistically significant at P<0.01 probability level to poverty with marginal effect of 0.0675921. This results show that monogamous marriage, divorce/separation and widowhood are negatively and significantly by 6% and is correlated with the probability of being poor. This implies that monogamous marriage has probability of reducing poverty polygamous marriage increases poverty. This supports the theory put forth by Anyanwu (2014), who said that monogamous marriage has the best chance of lowering poverty in Nigeria.

The household size had negative with marginal effect of 0.7702981 and was significant at P<0.05 probability level. The indicates that a unit increase in household size increases the likelihood of increasing the poverty level of household by 77%. This is consistent with research by Masood and Nasir (2014) and Adekoya (2014), which suggested that the number of children in a household increases its likelihood of poverty because they are often unproductive and consume a significant amount of household income for things like clothing, food, and school supplies.

Formal education in years have a positive impact to the level of poverty and is significant at P<0.05 level of probability with marginal effect of 1.123572, which implies that a unit increase in level of education will reduce the level of poverty of household by 112%. This is in line with the findings of Ume and Ochiaka (2016), who suggested that education makes people more objective when assessing innovation, which will improve their farm's output and reduce poverty.

Table 4. Logit Regression Result on Determinants of Poverty Status among the Respondents

Variable	Coefficient	Standard Error	Z- Statistics	Marginal Effect
Constant	8.052091	2.364506	3.41***	
Age (X_1)	-0.1930663	0.0374124	-5.16***	0.8244273
Sex (X_2)	-2.227702	0.8760867	-2.54**	0.1077759
Marital Status (X_3)	-2.694264	1.60295	-1.68*	0.675921
Household size (X_4)	-0.2609777	0.1104238	-2.36**	0.7702981
Formal Education (X_5)	0.116513	0.0471543	2.47**	1.123572
Primary Occupation (X_6)	1.091805	0.23677	4.61***	2.979647
Access to credit (X_7)	0.342112	0.1427336	2.40**	1.407918
Total annual income (X_8)	7.86e-06	3.34e-06	2.35**	1.000008
Annual remittances (X_9)	1.647845	0.4970097	3.32***	5.19577
Diagnostic Statistics				
Chi-square 184.68***				
Log-likelihood -60.374707				
Pseudo R^2 0.6047				
Specification test				
Hat	1.145496	0.1602512	7.15***	
Hatsq	0.0695403	0.240044	2.90	
Goodness-of-fit test				
Pearson chi2 (240) = 245.34				
Correctly classified 98.22%				

Source: Computed Field Data, 2024

Note: *** = Significant at 1%, ** = Significant at 5%, * = Significant at 10%

Primary occupation of the respondents in the study area have a positive effect on poverty and is significant at P<0.01. The marginal effect of primary occupation is 2.979647. This is an indication that the more the respondents engaged in the primary occupation the further away they will be the probability of being poor. This results is consistent with that of Kadurumba et al. (2010), who suggested that household heads' dedication to their primary occupation contributes to the decrease of poverty.

Rural household access to credit is significant at P<0.05 level of probability and has a positive effect poverty status with a marginal effect of 1.407918. This suggests that a unit increase in access to credit by farm household in the study area will increase the probability of the households to escape poverty 130%. This is consistent with research by Oyakhilomen and Kehinde (2016), who found that having access to credit positively affects income diversification, which in turn lowers poverty.

Household total annual income of the respondents in study area in naira was significant at P<0.05 level and has a positive effect on poverty with marginal effect of 1.000008. This implies that as the level of income of the household heads increases the lower will be the probability of being poor by 100%. Duniya and Sanni (2015), who proposed that an increase in revenue from a variety of money-generating activities lowers household poverty, support this finding.

Annual remittance from children and relatives has a positive effect on poverty status and statistically significant P<0.01 with marginal effect of 2.357952. This signifies that a unit increase in remittances of household will reduce the poverty of that household by 235%. This implies that remittances contribute to household income and consequently improved food security status of the households thereby reducing the probability of being poor. This finding is agrees with Odoh and Nwibo (2016) who revealed remittances have a potential multiplier effect, as they are associated with a poverty reduction.

Conclusion and Recommendation

Based on the finding it can be concluded that the level of poverty among farming household, showed that poverty incidence is 0.60 which indicate about 60% in variability of poverty of households of rural farming household within the poor. The poverty gap indicates that the poor will require 31% rise in their expenditure to become non-poor which translate into ₦34,420.22. The poverty severity index of the farming households shows 19% of the farming households that constitute the poorest among the farming household. This implies that poverty is severe among poor farming households. The result of Logit regression model indicates that seven out of the ten independent variables were positively related to poverty status of the respondents, while age, sex, marital status, household size, formal education, primary occupation, access to credit, total annual income and annual remittances were statistically significant at P<0.01, P<0.10, P<0.01, P<0.05, P<0.01, P<0.01, P<0.05, P<0.10 and P<0.05. Based on the finding it was recommended that, there is need for sufficient resources to develop infrastructure which includes roads network, electricity, water and telecommunication for easy evacution of farmers' output to urban area and transportation of inputs into the rural areas. There is a need for the farming households to have access to credit schemes, this could increase the off-farm activities that could generate more income for the household and thereby reduce their poverty.

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The Current Role of Turkey (*Meleagris gallopavo*) Breeding in Poultry Production: Türkiye and World Perspectives

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Abstract

This study examines the current role of turkey (*M. gallopavo*) breeding from both Türkiye and world perspectives. Globally, turkey meat production holds significant importance, particularly in the United States and the Europe. While turkeys ranked fourth in the world poultry stock (with shares of ducks, geese, and turkeys at 5.95%, 1.98%, and 0.66%, respectively, in 2023), they ranked second in Türkiye's poultry stock, albeit with a lower share (with shares of turkeys, geese, ducks and guinea fowl at 0.90%, 0.36%, and 0.11%, respectively, in 2023). In Türkiye, certain provinces, especially Manisa, Bolu, and İzmir, stand out in terms of live turkey stocks. In 2024, Şırnak and Van garnered attention by entering the top fifteen provinces in terms of turkey stock. An examination of the import data over the past five years reveals that the maximum level of imports for turkey poults and eggs was achieved in 2020, amounting to approximately 2.9 million units. According to provisional data for 2024, turkey carcass weights have increased by approximately 1.5 kg compared to the previous year, reaching about 11.63 kg, indicating that Türkiye could enter the top ten in the world rankings for turkey carcass yield in 2024. However, over the past decade, per capita turkey meat consumption has not exceeded 1 kg, with 2023 consumption at just 0.557 kg.

Key Words: *M. g. gallopavo, turkey meat, turkey stocks, turkey carcass yield*

Hindi (*Meleagris gallopavo*) Yetiştiriciliğinin Kümes Hayvancılığı Üretimindeki Güncel Rolü: Türkiye ve Dünya Perspektifleri

Özet

Bu çalışma, hindi (*M. gallopavo*) yetiştiriciliğinin mevcut rolünü hem Türkiye hem de dünya perspektifinden incelemektedir. Küresel olarak hindi eti üretimi, özellikle Amerika Birleşik Devletleri ve Avrupa'da büyük önem taşımaktadır. Hindiler, dünya kanatlı hayvan varlığında dördüncü sırada yer alırken (2023 yılında ördeklerin payı %5,95, kazların payı %1,98 ve hindilerin payı %0,66'dır), Türkiye'nin kanatlı hayvan varlığında daha düşük bir payla da olsa ikinci sırada yer almaktadır (2023 yılında hindilerin payı %0,90, kazların payı %0,36 ve ördeklerin payı %0,11'dir). Türkiye'de Manisa, Bolu ve İzmir başta olmak üzere bazı iller canlı hindi varlığı açısından öne çıkmaktadır. 2024 yılında Şırnak ve Van, hindi varlığı bakımından ilk on beş il arasına girerek dikkat çekmiştir.

Son beş yıllık ithalat verileri incelendiğinde, hindi palazı ve yumurtası ithalatının en yüksek seviyeye 2020 yılında ulaştığı ve yaklaşık 2,9 milyon adet olduğu görülmektedir. Geçici verilere göre 2024 yılında hindi karkas ağırlığının bir önceki yıla göre yaklaşık 1,5 kg artarak yaklaşık 11,63 kg'a ulaşması, Türkiye'nin 2024 yılında hindi karkas randımanı açısından dünya sıralamasında ilk ona girebileceğine işaret etmektedir. Bununla birlikte, son on yılda kişi başına hindi eti tüketimi 1 kg'ı geçmemiştir ve 2023 tüketimi sadece 0,557 kg'dır.

Anahtar Kelimeler: *M. g. gallopavo, hindi eti, hindi varlığı, hindi karkas randımanı*

Introduction

The turkey (Meleagris gallopavo), a large bird, belongs to the class Aves, order Galliformes, family Phasianidae, and subfamily Meleagridinae. The recognized subspecies of wild turkeys include *Meleagris gallopavo sylvestris* (Eastern wild turkey), *Meleagris gallopavo aneusta* (Moore's), *Meleagris gallopavo merriami* (Merriam's), *Meleagris gallopavo mexicana* (Gould's), *Meleagris gallopavo gallopavo* (Mexican), *Meleagris gallopavo intermedia* (Rio Grande), and *Meleagris gallopavo asceola* (Shehata and Hafez 2024). The modern domestic turkey is presumed to be descended from the South Mexican wild turkey (*Meleagris gallopavo gallopavo*). The domestication process was initiated approximately 2500 years ago by the indigenous peoples of North America.

The turkey was introduced to Europe in the early 16th century, initially brought to Spain before spreading to other royal households across Europe. Its favorable economic and quality traits have made it a preferred source of meat across various geographic regions globally. Domestic turkeys are selectively bred to be larger than their wild counterparts for meat production (Kyselý and Meduna, 2019; Hristakieva, 2021).

The most pivotal developments in turkey production have occurred in the United States, the United Kingdom, and France. Until the end of World War II, turkeys in the America were historically raised with seasonal breeding and both natural and artificial incubation in free-range systems. The practice of artificial incubation, hybrid breeding, and artificial insemination has facilitated selective breeding aimed at enhancing animal performance and quality (Shehata and Hafez 2024). Turkey production, though smaller compared to broiler production, has seen significant growth since the 1980s, with increasing relevance in both the European Union and the United States (Marchewka et al, 2013). In response to consumer demand, the employment of intensive genetic selection techniques to accelerate growth rates and enhance meat yields has resulted in increased body weight and a higher proportion of breast meat (Hiscock et al., 2022). The breeds listed contain commercial and industrial strains, local types and breeds recognised in many countries. The American Standard of Perfection has identified eight distinct varieties: Beltsville Small White, Black Turkey, Bourbon Red, Bronze, Narragansett, Royal Palm, Slate, and White Holland. Modern domesticated turkeys have been developed through crossbreeding and linebreeding programmes and are recognised as a single breed with eight distinct varieties based on plumage colour (Dahal et al., 2024).

Currently, the leading global specialized breeding companies within the turkey industry include the Erich Wesjohann Group, based in Germany (Aviagen Turkeys), which oversees the B.U.T. and Nicholas lines, and Hendrix Genetics, headquartered in the Netherlands (Hybrid Turkeys), responsible for the Converter and Grade Maker lines. Additionally, these enterprises offer less fast-growing turkey lines, such as various strains from Aviagen Turkeys (Hockenhull Turkeys). Hendrix Genetics, along with the smaller breeding company Kelly Turkeys in the United Kingdom, also provides diverse slow-growing hybrids suitable for free-range production (Kelly Turkey Farms) (Shehata and Hafez 2024).

This study aims to provide a comprehensive overview of the current role and significance of turkey breeding, based on the most recent data, from both a national perspective within Türkiye and a global context.

Turkey breeding in the world

According to the most recently published 2023 data (Fao, 2024), the share of turkey stock in other poultry, its share in slaughtered poultry stock and its share in poultry meat production worldwide are shown in figures 1-3 respectively.

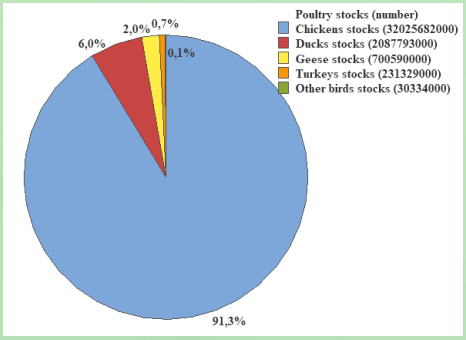


Figure 1. World poultry stock by species in 2023 (Fao, 2024)

In 2023, the world's poultry stock comprises chickens, ducks, geese, turkeys, and other poultry species, accounting for 91.3%, 5.95%, 1.98%, 0.66%, and 0.09%, respectively (Figure 1, Fao, 2024).

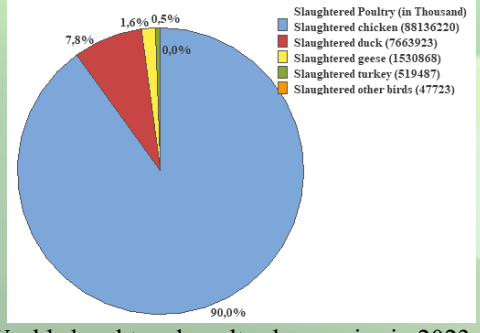


Figure 2. World slaughtered poultry by species in 2023 (Fao, 2024)

Figure 2 illustrates that in 2023, the world poultry slaughter data (expressed in thousands of poultry units) indicates that chickens constitute the highest percentage at 90.03%, followed by ducks at 7.83%, geese at 1.56%, and turkeys at 0.53%. Pigeons and other birds comprise a mere 0.05%, occupying the final position.

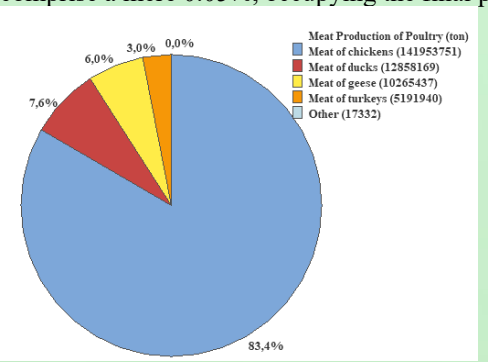


Figure 3. World poultry meat production by species in 2023 (Fao, 2024)

Figure 3 presents the production proportions of poultry meat by species in 2023. The respective percentages for chicken, duck, goose, turkey, pigeon and other birds are 83.36%, 7.55%, 6.03%, 3.05%, and 0.01%.

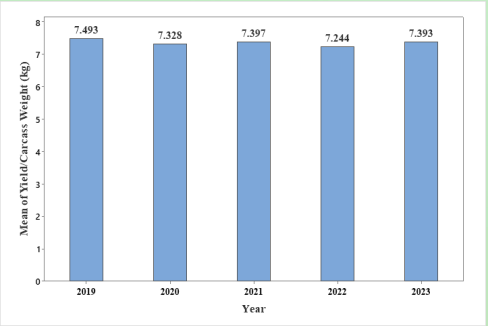


Figure 4. Mean turkey carcass weights in the world in the last five years (Fao, 2024)

Figure 4 presents the world means of turkey carcass weight over the past five years. Accordingly, the lowest average was recorded in 2022 at 7.244 kg, while the highest was in 2019 at 7.493 kg. Despite these values, there has been no significant numerical fluctuation in the world average over the last five years. On the other hand, Figure 5 shows the leading countries in terms of turkey carcass yield in each year of the last five years (2019-2023). According to this, China and/or China, Taiwan Province is quite high with values above 15 and ranked first every year.

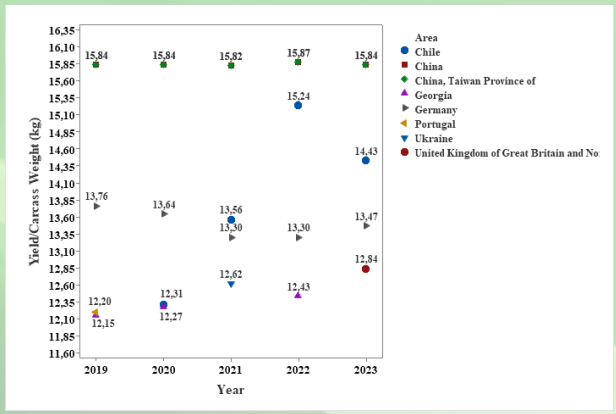
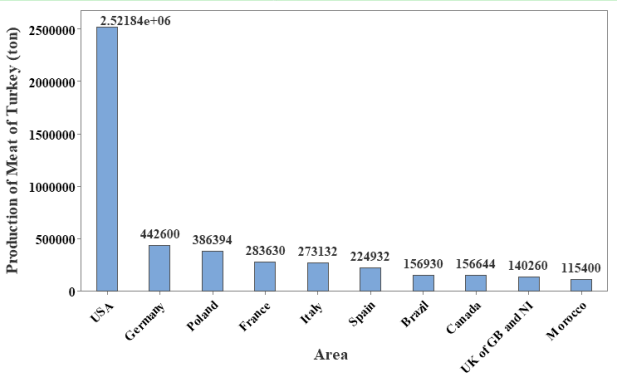


Figure 5. Leading five areas by turkey carcass yield in the last five years (alphabetically listed) (Fao, 2024)

Analyzing the average turkey meat production data from 2019 to 2023 (Figure 6) reveals that the United States of America holds a commanding lead. Following the USA, the top producers are Germany, Poland, France, Italy, Spain, Brazil, Canada, the United Kingdom of Great Britain and Northern Ireland, and Morocco, respectively.



Figures 6. Mean turkey meat production by leading 10 Areas: 2019-2023 (Fao, 2024)

Turkey breeding in Türkiye

Figure 7 presents the turkey stock in Türkiye for the years 2015-2024, along with the shares of other poultry species such as geese, ducks and guinea fowl, which may serve as alternatives to chickens. Despite turkeys ranking behind ducks and geese in the world stock (Figure 1), the proportion of turkey stock in Türkiye ranks second after chickens. While the proportion of turkeys within the poultry stock reached its highest level at 1.302% in 2019, the turkey stock achieved its maximum value (just under 4.8 million) within the last decade in 2020.

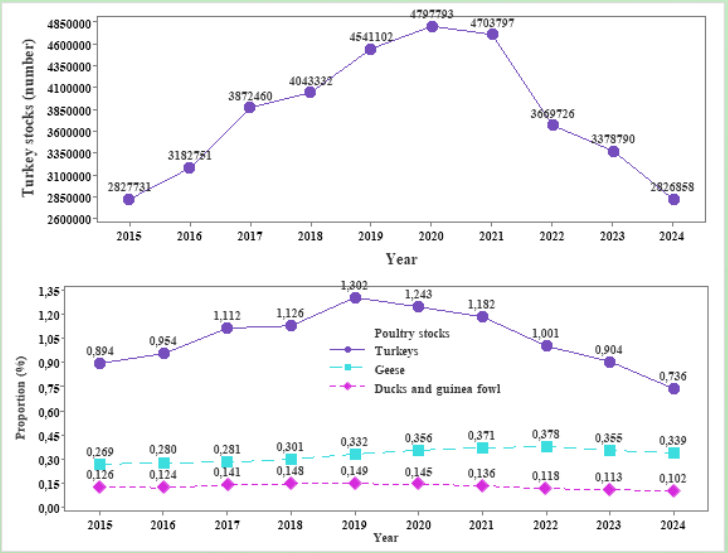


Figure 7. Turkey stock and its proportion within poultry in Türkiye (Tüik, 2024a)

Between 2015 and 2024, the top 15 provinces in terms of live turkey stocks accounted for 76.81%, 79.76%, 82.25%, 83.07%, 84.23%, 85.80%, 85.30%, 82.85%, 82.85%, 82.44%, and 82.46% of the total turkey stocks in these years, respectively (Figure 8, Tüik, 2024a). After 1995, utilizing the existing poultry farming knowledge, turkey farming has developed rapidly, especially in Bolu and İzmir due to the established poultry farming infrastructure (Koyubenbe and Konca, 2010). In the last decade, the live turkey stock in these provinces seems to have maintained its importance. And also, these four provinces, led by Manisa, Bolu, and İzmir, followed by Sakarya, are the leading provinces in terms of turkey stocks and have maintained their importance in the last decade. Except for the years 2018 and 2023, the highest turkey stock was in Manisa, while in these years, Bolu held the top position. In 2018, the proportional shares of Bolu and Manisa were 25.90% and 23.03%, and in 2023, they were very close at 27.70% and 27.64%, respectively. Additionally, in terms of live turkey stock, Şanlıurfa, Diyarbakır, and Muş consistently rank among the top fifteen provinces each year. These provinces represent the regions with the highest volumes of live turkey stocks across the country.

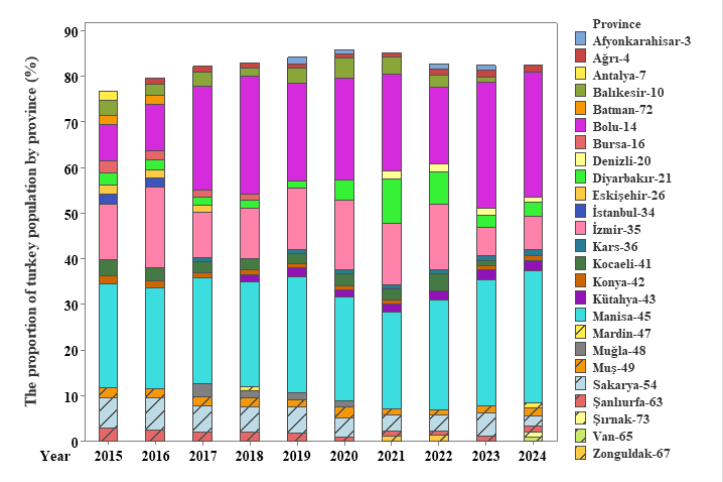


Figure 8. Leading 15 provinces by live turkey ratio over the past decade (alphabetically listed) (Tüik, 2024a)

When examining the provinces with the highest turkey stock ratios (Figure 8), it is observed that Bursa was included from 2015 to 2018, but not after 2019. Additionally, Eskişehir was included from 2015 to 2017, but not after 2018. Kocaeli was included from 2015 to 2023, but not in 2024. Balıkesir was included from 2015 to 2023, but its ranking gradually decreased, and it did not appear in 2024. Although Konya was often at the lower end of the top fifteen, it was included in every year except 2022. In 2024, Şırnak and Van entered the top fifteen for the first time. Although Mardin was in the top fifteen in 2018, it did not reappear until 2024, when it returned as one of the provinces with the highest turkey stock.

Table 1. Türkiye's turkey meat production and consumption (last decade) (Tüik, 2024a)

Year	Slaughtered turkey (thousand)	Turkey meat production (ton)	Yield/ Carcass weight (kg)[a]	Change in carcass yield (%)	Population of Türkiye	Turkey meat consumption per capita (kg)[b]	Chicken meat consumption per capita (kg)[b]
2015	5360	52723	9,836	-	78741053	0,670	24,247
2016	4664	46502	9,970	1,362	79814871	0,583	23,542
2017	5219	52363	10,033	0,632	80810525	0,648	26,441
2018	6780	69536	10,256	2,223	82003882	0,848	26,299
2019	6186	59639	9,641	-5,996	83154997	0,717	25,716
2020	6063	58211	9,601	-0,415	83614362	0,696	25,549
2021	5170	51301	9,923	3,354	84680273	0,606	26,520
2022	5593	53647	9,592	-3,336	85279553	0,629	28,353
2023	4681	47575	10,163	5,953	85372377	0,557	27,278
2024*	3508	40805	11,632	14,454	85664944	-	29,325

*: For the year 2024, data for the last three months of the year are not available, a: Yield or Carcass weight was found by dividing the turkey meat by the number of slaughtered turkeys, b: Per capita consumption is calculated by dividing the total produced meat by the population.

Table 2. Imports of turkey breeder poults and eggs in Türkiye in the last five years (number)

Year	Turkey poults; weight ≤ 185g, breeding stock	Turkey eggs; hatchery, breeding stock	Turkey eggs; hatchery, non-breeding stock	Total turkey egg imports
2020	49075	109200	2804400	2913600
2021	-	160516	1970200	2130716
2022	60830	-	1580400	1580400
2023	82070	-	250000	250000
2024*	66021	-	1909600	1909600

*: Data for 2024 is provisional, (Tüik, 2024b)

Considering that turkeys start laying at about eight months (Özlü et al., 2015), six months laying period (between 31 and 56 weeks of age of the turkey) (Filiz, 2024) and reach slaughter age at about four months (Sipahi and Cevger, 2021), the increase in turkey carcass weight in 2024 (Table 1) can be attributed to increased imports of turkey chicks and eggs in 2022 and 2023. Imported breeding flocks may grow faster, be more productive and have

better nutrition and care than in previous years. However, an examination of the egg import data for the last five years shows that there is no dramatic increase in 2022 and 2023 (Table 2), at least in terms of numbers, and even a numerical decrease until 2023, while turkey poult stocks imports increase in 2023. This increase in carcass yield can be attributed to the use of high-performance genotypes and improved feeding and environmental conditions. On the other hand, turkey carcasses exhibit significant variations based on breed, gender, genetic selection, breeding system, age at slaughter, pre-slaughter treatment (Fry et al., 1962; Çelik et al., 2018). Therefore, the turkey varieties preferred in breeding in 2024 may have exhibited higher performance in terms of carcass yield or longer fattening periods compared to previous years.

In terms of turkey carcass yield, Türkiye has progressively risen in the world rankings from 2019 to 2023, occupying the 23rd, 21st, 17th, 18th, and 16th positions, respectively (Fao, 2024). As shown in Table 1, the carcass yield in 2024 increased by 14.45% compared to the previous year, amounting to approximately 1,5 kg. Consequently, it is projected that Türkiye could enter the top 15 in the world rankings for carcass yield in 2024.

Per capita turkey meat consumption has not even exceeded 1 kg in the last decade. In 2023, per capita turkey meat consumption was only 0.557 kg, whereas chicken meat consumption was approximately 49 times higher, with 27.278 kg consumed per capita (Table 1).

Conclusion

Among poultry species, turkeys have the potential to become a significant meat production sector globally in certain regions. The increase in turkey carcass weight in Türkiye may have been achieved through the application of advanced breeds and modern breeding methods. These advancements suggest that turkey meat production may continue to rise in the future. However, per capita turkey meat consumption in Türkiye remains at low levels.

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ID: 341

Gıda Güvenliğini Destekleme ve Sürdürülebilir Tarımı Teşvik Etmede Yabani Yenilebilir Sebzelerin Potansiyel Rolü: Doğu Karadeniz Bölgesi Örneği

Hatice Filiz Boyacı

Bahçe Bitkileri Bölümü, Ziraat Fakültesi, Recep Tayyip Erdoğan Üniversitesi, Rize, Türkiye
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Özet

Sebze tarımında giderek artan nüfusun gıda ihtiyacından doğan gıda arz güvenliğini desteklemek için birim alandan daha fazla ürün elde etmeye odaklanılmıştır. Ancak yapılan yoğun tarımsal faaliyetler üretim üzerinde baskı oluşturmuştur. Sebzelerin sürekli aynı ortamda yetiştirilmesinden kaynaklanan toprakların verimsizleşmesi, kimyasal ilaç ve gübrelerin bilinçsiz ve fazla kullanımı, hastalık ve zararlıların yoğunluğu ciddi verim ve kalite kayıplarına neden olmaktadır. Bunlara ilaveten küresel iklim değişikliğinin etkisiyle artan aşırı hava olaylarının yol açtığı yüksek sıcaklık, kuraklık, soğuk, tuzluluk, ani yağışlarla meydana gelen seller, kentleşme ve sanayileşmenin sonucu olarak artan sera gazları salınımı, ağır metaller özellikle açıkta yetiştiriciliği tehdit etmektedir. Bitki ıslahçıları yeni çeşitlerin geliştirilmesinde bir yandan verim ve kalite sorunlarını çözmeye çalışırken diğer yandan stres koşullarına dayanıklılığı artırma çabasındadırlar. Bununla birlikte sürekli değişen koşullarda çoklu strese maruz kalan kültür sebzelerinde stres faktörlerine karşı direnç geliştirmek ıslah sürecini uzatmaktadır. Çoklu dayanım kazandırmak maliyetli bir süreç olup kısa vadede çözüm bulmak zordur. Dayanıklılık genleri için türün yabani akrabalarından yararlanılmakta, ıslah sürecinde yabani genitörden gelen istenmeyen genlerin eleminasyonu uzun zaman almaktadır. Oysa doğada bulunan yabani yenilebilir bitkiler halen güçlü genetik yapıları ile stres koşullarına dayanım sağlamakta ve yaşamlarını sürdürebilmektedirler. Yerelde tüketilen bu bitkiler gıda açığını kapatmada kısa vadede çözüm sunabilmektedir. Ancak bunların doğal yayılış alanlarının vadilerde ve yamaçlarda olması doğadan toplanan bu ürünlerin tedariğini güçleştirmektedir. Yabani yenilebilir sebzelerin kültüre alınarak yetiştirilmesi, devamlı bir şekilde tedarik edilmesini sağlayabilir ve tarımsal üretim sistemlerinde açık kapatılabilir. Türkiye sebze olarak tüketilebilecek yabani yenilebilir türlerin biyoçeşitliliği açısından oldukça zengindir. Yerelde kullanılan bu türlerden kültüre alınma potansiyeli taşıyanlar mevcuttur. Doğu Karadeniz Bölgesi bu anlamda önemli bir örnektir. Yüksek nem ve her mevsim yağışlı, asidik karakterde toprağı olan bölgeye adapte olan bazı yenilebilir yabani yapraklı sebzelerin yüksek adaptasyon yetenekleri ile farklı coğrafik koşullarda da yetiştirilme potansiyeli taşıdıkları kanıtlanmıştır. Bunlar bölgenin sürdürülebilir gıda sistemleri için yerel çözüm sunmakla kalmayıp, gıda güvenliğine alternatif yaklaşım olarak değerlendirilebilir.

Anahtar Kelimeler: *İklime dayanıklı ürünler, biyoçeşitlilik, kültüre alma, yapraklı sebzeler, yerel üretim*

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Farklı Işık Spektrumları Köksüz Su Mercimeğinin (Wolffia arrhiza) Morfolojik Yapısını Etkiler

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Özet

Su mercimekleri (Lemnaceae) beş cins (*Spirodela*, *Lemna*, *Landoltia*, *Wolffia* ve *Wolffiella*) ve 36 türden oluşan, suda serbest yüzen çiçekli bitkilerdir. Dünya'nın en küçük ve en hızlı büyüyen angiospermleri olarak bilinirler. Su mercimekleri 1.5 cm ile 1 mm'den küçük boyutlara kadar değişen türler içerir. Bu ailenin en küçük bireyleri olan köksüz su mercimeği *Wolffia* (su unu, su yumurtaları) yüksek protein içeriği ile dikkat çekmektedir. Bitki bazlı protein kaynağı olarak önemli bir pazar potansiyeline sahip olan *W. arrhiza* ve *W. globosa* üzerine son yıllarda daha fazla odaklanılarak üretimi yapılmadır. Bu çalışmada, iklimlendirme kabininde farklı LED ışıklar altında (beyaz, kırmızı, mavi ve mor) ve laboratuvar ortamında gün ışığında yetiştirilen *W. arrhiza*'nın morfolojik yapısı (en ve boy uzunluğu) incelenmiştir. Stereo mikroskopta yapılan incelemelerde, en ölçümleri sırasıyla mavi > gün ışığı > beyaz > mor > kırmızı ışıklarda, boy ölçümleri ise sırasıyla gün ışığı > mavi > beyaz > mor > kırmızı ışıklarda tespit edilmiştir. Araştırma sonuçlarına göre farklı ışık spektrumlarının *W. arrhiza*'nın morfolojik yapısı üzerinde etkili olduğu gözlenmiştir. Mavi LED altında yetişen *W. arrhiza* daha iri iken kırmızı LED örnekleri daha küçük yapılıdır. Hedefe yönelik (gıda, yem, biyoteknoloji, biyoyakıt, biyolojik arıtma gibi) büyük biyokütleli, verimli, optimum ve sürdürülebilir üretim amacıyla, geleneksel ışıkların yanı sıra LED uygulamaları su mercimeği yetiştiriciliğinde kullanılabilir. Bunun için su mercimeği türlerine uygun ışık tercihinin seçilmesi gerekir.

Anahtar Kelimeler: *Köksüz su mercimeği, Wolffia arrhiza, LED ışık, ışık dalga boyu, bitki büyümesi*

Different Light Spectrums Affect the Morphological Structure of Rootless Duckweed (*Wolffia arrhiza*)

Abstract

Duckweeds (Lemnaceae) are free-floating flowering plants in water, consisting of five genera (*Spirodela*, *Lemna*, *Landoltia*, *Wolffia* and *Wolffiella*) and 36 species. They are known as the smallest and fastest-growing angiosperms on Earth. Duckweeds include species ranging in size from 1.5 cm to less than 1 mm. The smallest members of this family, the rootless duckweed *Wolffia* (watermeal, water eggs), are notable for their high protein content. *W. arrhiza* and *W. globosa*, which have an important market potential as plant-based protein sources, have been more focused on and produced in recent years. In this study, the morphological structure (width and length) of *W. arrhiza* grown under different LED lights (white, red, blue, and violet) in an air conditioning cabinet and under daylight in the laboratory was investigated. In the stereo microscope examinations, the width measurements were determined under blue > daylight > white > violet > red light, and the length measurements were determined under daylight > blue > white > violet > red light, respectively. According to the results of the research, it was observed that different light spectra were effective on the morphological structure of *W. arrhiza*. *W. arrhiza* grown under blue LED were larger, while red LED samples were smaller. For targeted (food, feed, biotechnology, biofuel, biological treatment, etc.) large biomass, efficient, optimal, and sustainable production, LED applications can be used in duckweed cultivation alongside conventional lights. For this, it is necessary to choose the appropriate light preference for duckweed species.

Key Words: *Rootless duckweed, Wolffia arrhiza, LED light, light wavelength, plant growth*

ID: 343

Interfacial Activity and Stabilization Mechanisms of Food Colloids in Pickering Emulsions

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Abstract

The interfacial deformation and interfacial rheology behavior of food colloids are one of the important factors affecting their emulsification performance. The interfacial layer formed by food colloids adsorbed on the oil-water interface plays an important role in emulsion stability. However, these issues have not yet been sufficiently clarified. Based on the finding that colloidal particles used in food significantly improve the emulsifying property of Pickering emulsions, the effects of food colloids on the structure properties, interfacial deformation, and interfacial rheology behavior and their relationship with emulsification performance were investigated in this study. The results showed that food colloids at the interface of Pickering emulsions promoted the initial adsorption of particles and accelerated the formation of viscoelastic interfacial films, improving emulsification performance. In addition, food colloids imparted moderate viscosity and fluidity to the interfacial layers, which could combat the destabilization caused by oil droplet deformation. This study is believed to provide new insights into understanding and fine-tuning the interfacial behavior of food colloids.

Key Words: *interfacial behavior, food colloids, emulsion stability, Pickering emulsions, O/W interface*

ID: 344

Paraprobiyotiklerin Kısa Zincirli Yağ Asitleri Üretimindeki Rolü: Mikrobiyal Etkileşimler ve Potansiyel Mekanizmalar

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Özet

Son yıllarda, kısa zincirli yağ asitleri (KZYA) sağlık üzerindeki potansiyel faydalarıyla dikkat çekmekte ve giderek daha fazla araştırılmaktadır. KZYA'lar, bağırsak mikrobiyotası tarafından diyet lifleri ve dirençli nişasta gibi fermente edilebilir karbonhidratların metabolizması sonucu üretilen biyoaktif bileşiklerdir. Başlıca asetat, propiyonat ve bütirattan oluşan bu metabolitler, bağırsak bariyer bütünlüğünün korunması, antiinflamatuar yanıtların düzenlenmesi ve enerji homeostazının sağlanması gibi önemli fizyolojik süreçlere katkıda bulunur. Son dönemde, canlı olmayan probiyotikler olarak tanımlanan paraprobiyotiklerin sağlık üzerindeki etkileri artan bir ilgi görmektedir. Bu derleme, paraprobiyotiklerin bağırsak mikrobiyotasıyla ilişkili KZYA üretimine etkilerini inceleyen mevcut çalışmaları değerlendirmeyi amaçlamaktadır. Araştırmalar paraprobiyotiklerin bağırsak mikrobiyotasının kompozisyonunu modüle ederek belirli bakteri gruplarının aktivitesini değiştirebileceğini ve bunun sonucunda asetat, propiyonat ve bütirat üretimini etkileyebileceğini göstermektedir. Bununla birlikte, paraprobiyotiklerin KZYA üretimi üzerindeki spesifik etkileri; mikroorganizma türü, inaktivasyon yöntemi ve substrat çeşitliliği gibi birçok faktöre bağlıdır. Paraprobiyotiklerin etki mekanizmalarının daha iyi anlaşılması, prebiyotik ve postbiyotiklerle olan etkileşimlerinin araştırılması, gelecekte bu alanda yapılacak çalışmalara önemli katkı sağlayacaktır.

Anahtar kelimeler: *paraprobiyotik, kolonik fermantasyon, bağırsak mikrobiyotası, asetik asit, bütirik asit, propiyonik asit*

ID: 345

Waterlogging Stress in Ornamental Plants, Effects, Tolerance Mechanisms: A rewiew

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Abstract

In recent years, the frequency and severity of floods have increased due to global warming associated with climate change. Flooding is a significant abiotic stress factor that directly affects plant growth, development, and survival, and it has considerable impacts on biodiversity. In agriculture, research on flooding stress has primarily focused on crops with high strategic importance. However, in ornamental plants, the amount of research remains limited.Flooding induces substantial morphological and physiological changes in plants, depending on the species, the duration of inundation, and the prevailing environmental conditions. The main objectives of this review are to examine the effects of flooding stress on ornamental plants and to highlight the morphological, physiological, biochemical, genetic, and molecular mechanisms involved in flood tolerance.

In recent years, several strategies have been explored to mitigate the adverse effects of flooding on plants. These include the selection of tolerant species and cultivars, nutrient supplementation, hormone treatments, and the application of biostimulants. Such mechanisms support plant survival by enhancing oxygen uptake, reducing toxic metabolite accumulation, and maintaining energy production under hypoxic conditions.

The findings of current studies are crucial for developing strategies to manage flood-induced stress, guiding the selection of suitable ornamental plants for flood-prone landscape areas, promoting sustainable landscape designs, and minimizing economic losses in the ornamental horticulture sector. Furthermore, it is essential for ornamental plant breeding programs to focus on the development of waterlogging-tolerant cultivars.

Key Words: *Water flooding, abiotic stress, species selection, landscape*

Süs Bitkilerinde Su Baskını Stresi, Etkileri, Tolerans Mekanizmaları: Bir inceleme

Özet

Son yıllarda iklim değişikliğinin neden olduğu küresel ısınma ile birlikte su baskınlarının sıklığı ve şiddeti de gittikçe artmaktadır. Su baskını, bitkilerin büyümesi, gelişimi ve hayatta kalmasını doğrudan etkileyen, biyoçeşitlilik üzerinde önemli etkiye sahip olan abiyotik stres faktörlerinden birisidir. Tarımda bu konuda yapılan araştırmalar daha çok stratejik değeri yüksek bitkiler üzerinde yoğunlaşmıştır. Süs bitkilerinde ise daha sınırlı sayıda araştırma mevcuttur. Su baskını bitkinin türüne, su altında kalma süresine ve çevresel koşullara bağlı olarak önemli morfolojik ve fizyolojik değişimlere neden olmaktadır. Bu incelemenin temel amaçları, su baskını stresinin süs bitkilerindeki etkilerini ortaya koyarak morfolojik, fizyolojik, biyokimyasal, genetik ve moleküler tolerans mekanizmalarını ele almaktır. Sel baskını stresinin bitkilerdeki olumsuz etkisini azaltmak için son yıllarda bazı uygulamalar üzerine yoğunlaşılmıştır. Tolerant tür ve çeşit seçimi, bazı besin elementi uygulamaları, hormon ve biyostimulant uygulamaları bunlardan bazılarıdır. Bu mekanizmalar, bitkinin oksijen alımını artırarak, toksik birikimini önleyerek ve enerji üretimini sürdürerek hayatta kalmasını sağlar.Yapılan çalışmalar, sel kaynaklı stresi azaltmaya yönelik stratejilerin geliştirilmesi, sele meyilli peyzaj alanlarında süs bitkilerinin seçimine ilişkin değerli bilgilerin sağlanması, sürdürülebilir peyzaj tasarımlarının geliştirilerek süs bitkileri sektöründeki ekonomik kayıpların azaltılabilmesi bakımından önemlidir. Süs bitkileri yetiştiricileri için de su basmasına dayanıklı çeşitlerin geliştirilmesi gereklidir.

Anahtar Kelimeler: *Su taşkını, abiotic stress, tür seçimi, peyzaj*

Introduction

Waterlogging (flooding) is caused by environmental factors such as heavy rainfall, river overflow, storms, over-irrigation, poor soil drainage, and low soil permeability (Figure 1) (Manghwar et al., 2024). It has become increasingly common in many parts of the world due to global climate change and rapid urbanization (Pan et al., 2025). According to recent data, areas affected by flooding cover approximately 13% of the Earth's surface (Sangiorgio et al., 2020). In 2016, a total of $217 million was spent on flood damage and control in the United States—3.4 times more than the costs associated with droughts (Jia et al., 2021). This trend has had a significant impact on urban ecosystems.In response, sponge city models—an innovative approach to mitigating waterlogging—have been adopted in many countries around the world in recent years (Pan et al., 2025). Examples

include Low Impact Development (LID) in the United States, Sustainable Urban Drainage Systems (SUDS) in France, and Water Sensitive Urban Design (WSUD) in Australia (Ning et al., 2017).

Waterlogging is one of the most critical abiotic stress factors that negatively affect plant growth and development. Flood stress manifests in two primary forms: complete submergence of the plant (both root and shoot), leading to anoxia, and partial submergence affecting only the root zone, resulting in hypoxia (Zhao et al., 2018). This stress directly impacts plant metabolism and survival, causing significant physiological, morphological, and biochemical changes. The extent and nature of these changes depend on the plant species, the duration of inundation, and environmental conditions.Plants develop various resistance mechanisms under waterlogging stress, and understanding these mechanisms is essential for selecting flood-tolerant species and guiding genetic improvement studies (Pan et al., 2025).

Research in this area has largely concentrated on agricultural crops that are vital for human nutrition and health. In contrast, studies focusing on ornamental plants remain limited. Waterlogging stress can severely affect the morphology of leaves, flowers, and stems in ornamental species, thereby reducing their aesthetic and commercial value.

Increasing research on this topic may contribute to the development of flood-tolerant ornamental plants, offering practical solutions for waterlogging problems encountered in landscape design and urban green space planning. This review discusses the morphological, physiological, and biochemical effects of waterlogging on plant growth, yield, and quality, as well as the adaptive mechanisms plants employ in response to this stress.



Fig 1. Causes of waterlogging

A.Physiological, Morphological and Biochemical Effects of Waterlogging on Plant Growth and Development

A.1. Physiological Changes

The earliest physiological response of plants to water accumulation in the soil is stomatal closure.

A.1.1. Stomatal Closure

Under waterlogging conditions, plants perceive the stress signal and respond by closing their stomata to minimize water loss from the leaves. However, this adaptive response also limits carbon dioxide uptake, thereby reducing photosynthesis and negatively affecting plant growth (Ashraf, 2012; Yin et al., 2012; Zhang et al., 2024).

A.1.2. Decrease in Photosynthetic Capacity

When air-filled pores in the soil are occupied by water, gaseous exchange becomes restricted. Oxygen and other essential gases diffuse slowly through water-saturated soils, limiting their availability to both plant roots and soil microorganisms. This impaired gas exchange reduces the plant's photosynthetic efficiency (Sharma et al., 2021; Zhang et al., 2024; Pan et al., 2025).

A.1.3. Oxygen Deficiency (Hypoxia and Anoxia)

During waterlogging, plant roots experience oxygen deficiency. This inhibits aerobic respiration and shifts energy metabolism toward less efficient anaerobic pathways, leading to decreased ATP production. Fermentation processes increase, resulting in the accumulation of byproducts such as CO_2, methane, and volatile fatty acids in the rhizosphere. Additionally, high temperatures can accelerate oxygen depletion in saturated soils (Yavaş et al., 2011; Lindsey et al., 2024). In general, oxygen levels in waterlogged soils fall below critical thresholds for plant growth within approximately 45 to 96 hours (Özcan, 2020).

A.1.4. Decrease in Nutrient Uptake

Under waterlogging conditions, even in tolerant plant species, growth rate, nutrient uptake, and the root-to-shoot ratio are significantly reduced. Oxygen deficiency in the root zone disrupts ion balance by decreasing the uptake of potassium (K^+) relative to sodium (Na^+), and impairs the transport of K^+ to aerial plant parts. Research has shown that the adverse effects of waterlogging are not primarily due to the toxic accumulation of Na^+ or Fe^{2+}, but

rather to reduced concentrations of essential nutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg).Denitrification and nutrient leaching are key processes that decrease soil nitrogen availability under anaerobic conditions. Denitrification refers to the microbial conversion of nitrite (NO_2^-) or nitrate (NO_3^-) into gaseous nitrogen (N_2) compounds, which are released into the atmosphere, thereby leading to nitrogen deficiency in the soil. In response to nutrient scarcity, plants may remobilize internal nutrient reserves by degrading chlorophyll (Chl), which can impair chlorophyll biosynthesis. This disruption promotes the generation of reactive oxygen species (ROS), ultimately resulting in oxidative damage and cell death (Kudoh and Sonoike, 2002; Yavaş et al., 2011; Ashraf, 2012; Akhtar and Nazir, 2013). Soil pH generally increases during waterlogging, primarily due to the dissolution of carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) compounds. In saline soils, this condition can exacerbate salt stress, often leading to rapid plant death under prolonged water accumulation (Yavaş et al., 2011; Panda and Barik, 2021).

A.2.Morphological Changes

A.2.1.Root Rot

In the absence of oxygen, root growth is restricted, and processes such as root elongation, thickening, and lateral root formation are either slowed or completely inhibited. Oxygen deficiency leads to the accumulation of toxic compounds such as ethanol and acetaldehyde, as well as mineral ions like nitrites and ferrous ions in root tissues (Sharma et al., 2021; Liu et al., 2021; Pan et al., 2025). These accumulations can cause root cell death and initiate tissue decay processes (Pan et al., 2025). The resulting damage impairs the plant's ability to absorb water and nutrients, ultimately leading to plant death.

Under saline conditions, waterlogging further exacerbates stress by inhibiting the root's ability to exclude salts. This leads to excessive salt uptake and accumulation in the shoots, intensifying toxicity and physiological damage. Waterlogging responses and subsequent recovery strategies in *Paeonia* species are illustrated in Figure 2 (Zhou et al., 2024).

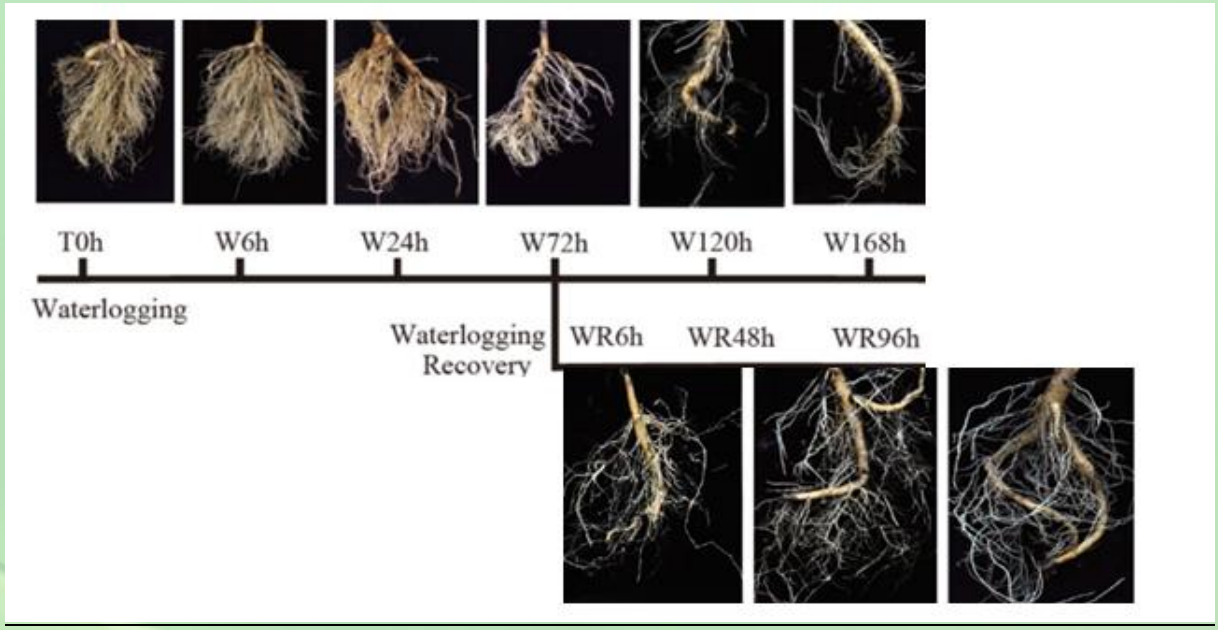


Fig 2. Waterlogging and recovery application in peony plants (Zhou et al., 2024-changed)

A.2.2.Growth Retardation and Decrease of Flowering

Under prolonged flooding conditions, the above-ground parts of plants are also adversely affected. Stem thickening, growth inhibition, or excessive elongation may occur as physiological responses to stress (Pan et al., 2025). In a study on narrow-leaved zinnia (*Zinnia angustifolia*), plants exposed to flooding exhibited significantly reduced height compared to the control plants; however, they retained a high ornamental value. Such morphological responses may represent an adaptive mechanism to reduce flooding-induced damage (Yang et al., 2020).Flooding stress also impacts reproductive development. Flowering may be delayed, reduced, or completely suppressed as the plant prioritizes energy conservation over reproduction (Butsayawarabat et al., 2019; Jacob and Sumiya, 2022).

A.2.3. Leaf Yellowing and Dropping

Due to chlorophyll degradation, plants subjected to waterlogging often exhibit visible symptoms such as yellowing, wilting, and leaf curling. In addition, increased ethylene production under stress conditions may lead to premature leaf abscission and inhibit the formation of new leaves (Zhao et al., 2018; Zhang et al., 2023).

In chrysanthemum (*Chrysanthemum morifolium*), prolonged exposure to waterlogged conditions significantly increased the thickness of palisade and spongy parenchyma layers (Yin et al., 2012). However, in *Celosia spp.* and

Amaranthus spp.—commonly referred to as medallion flowers—leaf thickness was found to decrease under water-saturated conditions (Yang et al., 2020).Short-term waterlogging did not significantly affect the plant height, leaf length, or leaf area of the herbaceous peony (*Paeonia lactiflora*), but it did significantly reduce the root-to-shoot ratio (Liu et al., 2021).

A.3.Biochemical Changes

A.3.1.Increase in Reactive Oxygen Species (ROS)

Under waterlogging stress, oxygen deficiency leads to elevated levels of reactive oxygen species (ROS), which disrupt various cellular metabolic processes in plants. Molecular oxygen is gradually reduced within the cell, resulting in the formation of different types of ROS. These include singlet oxygen ($^1O_2$), superoxide anion (O_2^-), hydrogen peroxide (H_2O_2), and hydroxyl radical (OH•). Under normal physiological conditions, the concentrations of these reactive species are tightly regulated and remain at low levels (Büyük et al., 2012).

ROS are produced in plants even under non-stress conditions; however, their accumulation is limited by enzymatic and non-enzymatic antioxidant defense systems that maintain cellular redox homeostasis. Under stress conditions such as waterlogging, the efficiency of these antioxidant systems declines, thereby promoting ROS overproduction and leading to their accumulation within plant tissues (Yin et al., 2009; Ashraf, 2012).

A.3.2.Increase in Lipid Peroxidation

Lipid peroxidation in plants is promoted by reactive oxygen species (ROS), leading to elevated levels of oxidative damage. Increased lipid peroxidation compromises cell membrane integrity, impairs photosynthetic activity, and reduces overall stress tolerance. One of the key byproducts of lipid peroxidation, malondialdehyde (MDA), can bind to proteins and DNA, thereby disrupting their structural and functional integrity (Liu et al., 2021).Zhou et al. (2019) reported that, under waterlogging conditions, leaf pigment content decreased in all tested poplar cultivars, while the levels of MDA and proline (Pro) increased. Similarly, in a comparative study of flood-susceptible and flood-tolerant chrysanthemum cultivars, MDA content was significantly higher in the susceptible cultivar, whereas it remained relatively stable in the tolerant one (Yin et al., 2009). Elevated MDA levels are considered indicative of weaker antioxidant defense systems and higher oxidative stress (Zhang et al., 2019).

A.3.3.Protein Oxidation and Impairment of Enzyme Activity

Protein oxidation occurs as a result of damage caused by reactive oxygen species (ROS), such as superoxide anion (O_2^-) and hydrogen peroxide (H_2O_2), which alter the structure and function of proteins. This oxidative damage impairs enzymatic activity, thereby disrupting key biochemical reactions. When photosynthetic enzymes are affected, energy production through photosynthesis is significantly reduced.

Under conditions of severe oxidative stress, the accumulation of oxidized or misfolded proteins can trigger the activation of programmed cell death (PCD) pathways, ultimately leading to plant cell death (Manghwar et al., 2024; Pan et al., 2025).

A.4. Hormonal Changes

Ethylene is a phytohormone that promotes plant growth at low concentrations. Under stress conditions, ethylene levels generally increase due to the accumulation of 1-aminocyclopropane-1-carboxylic acid (ACC), a key precursor in the ethylene biosynthetic pathway. ACC accumulation is thought to negatively affect plant growth, particularly by inhibiting root development (Nadaem et al., 2014). Elevated ethylene production can lead to premature leaf abscission and contribute to root damage under hypoxic stress.

In a study conducted on two waterlogging-tolerant *Chrysanthemum* (syn. *Dendranthema spp.*) cultivars, ethylene was reported to accelerate the onset of programmed cell death (PCD) under waterlogged conditions (Yin et al., 2013). Waterlogging also elevates abscisic acid (ABA) levels, which induces stomatal closure to minimize transpirational water loss (Akhtar and Nazir, 2013). Conversely, the levels of growth-promoting hormones such as gibberellic acid (GA_3) and cytokinins are typically reduced under waterlogged conditions (Sanghera and Jamwal, 2019).

B.Mechanisms of Plant Resistance to Waterlogging

The ability of plants to survive waterlogging is associated with their developed resistance to the stress factor, which consists of morphological, physiological, biochemical, genetic, and molecular tolerance mechanisms (Figure 3).

B.1. Morphological and Anatonomical Adaptation

Morphological and anatomical adaptations developed by plants in response to waterlogging include the formation of aerenchyma tissue, adventitious root development, internode elongation, gas film formation, and the development of radial oxygen loss (ROL) barriers. These adaptations help reduce oxygen demand and improve gas exchange under hypoxic conditions.

B.1.1. Elongation of Apical Meristems

Rapid internode elongation is a key adaptation to waterlogging, enabling plants to escape the anoxic zone by reaching above the water surface and restoring access to atmospheric oxygen for aerobic respiration (Pan et al., 2021).

B.1.2. Formation of Aerenchyma

Under waterlogged conditions, some plants develop specialized air-filled tissues called aerenchyma in their roots and stems to facilitate internal oxygen transport (Akhtar and Nazir, 2013; Zhang et al., 2023; Pan et al., 2025). Aerenchyma channels deliver oxygen to the root system while simultaneously allowing the removal of CO_2 and toxic metabolites from water-saturated tissues (Pan et al., 2021).

B.1.3. Adventitous Root Growth

Plants exposed to flooding often form adventitious roots along the stem to enhance oxygen uptake. This response is especially prominent in aquatic and semi-aquatic species and helps compensate for impaired function of the primary root system (Ashraf, 2012; Pan et al., 2025). The formation of adventitious roots is influenced by factors such as water depth, oxygen availability, light penetration, and dissolved CO_2 concentration (Sharma et al., 2021).

B.1.4. Gas Film Formation

In certain aquatic or semi-aquatic plants, a thin gas film forms on the leaf surface under submerged conditions (Figure 4). This gas film facilitates more efficient gas exchange between the plant and its environment, thereby supporting continued aerobic respiration and photosynthesis (Pan et al., 2021).

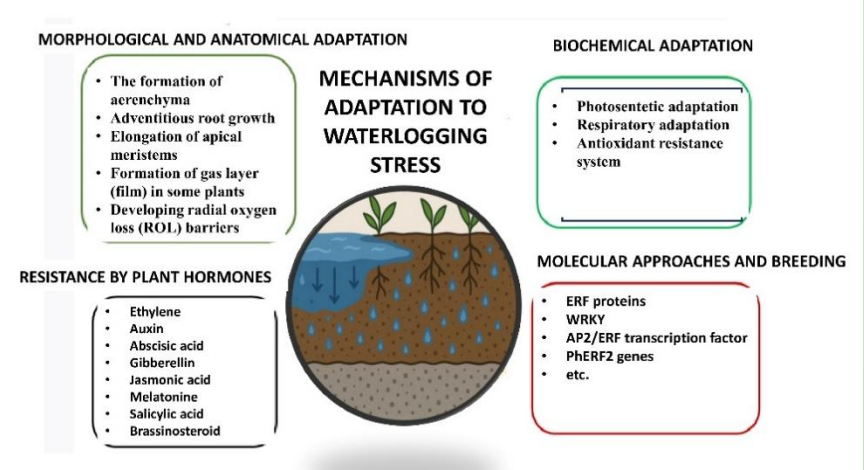


Fig 3. Mechanisms of resistance developed by plants against waterlogging stress

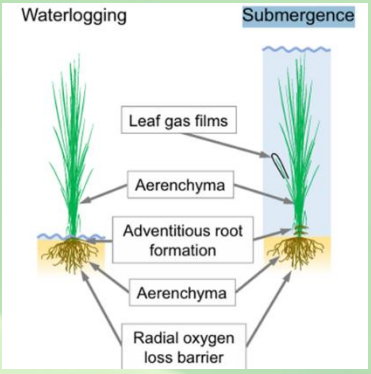


Fig 4. Gas film formation in submergence plants (Kuroha and Ashikari, 2020)

B.1.5. Developing radial oxygen loss (ROL) barriers

Oxygen produced in the leaves—the primary site of photosynthesis—is transported to the roots via specialized air-filled tissues known as **aerenchyma**. Upon reaching the root tip or other root zones, this oxygen can diffuse radially from the root into the surrounding environment. This process, termed **radial oxygen loss (ROL)**, occurs especially in hypoxic or anoxic soils where oxygen is scarce.

ROL can offer several physiological benefits. It creates an oxygenated zone around the root surface, which reduces the toxicity of harmful substances such as reduced sulfur compounds (e.g., hydrogen sulfide) and supports the survival of beneficial aerobic microorganisms (Figure 5). However, when significant amounts of oxygen are lost to the environment before reaching the root tip, it can result in oxygen deficiency at the root apex, thereby limiting root growth. To mitigate this, some plant species develop a physical barrier composed of substances like **suberin**

or **lignin** within the outer layers of the root. This barrier restricts radial oxygen leakage, allowing more oxygen to reach the root tip and enhancing root survival and growth under flooded conditions (Pan et al., 2021).

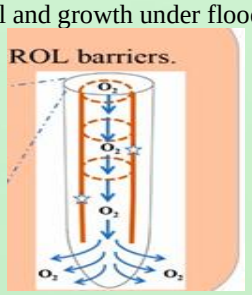


Fig 5. Radial O_2 loss (ROL) (Jia et al., 2021).

B.2.Biochemical Adaptation

Biochemical adaptations under waterlogging stress include the activation of protective enzymes that detoxify harmful substances and support essential metabolic functions, enabling plant survival in oxygen-deprived environments.

B.2.1.Photosynthetic Adaptation

Photosynthetic adaptation refers to the plant's ability to adjust its photosynthetic processes in response to environmental variables such as light intensity, water availability, temperature, and CO_2 concentration. These adaptations help plants maintain energy production under stress conditions.

Photosynthetic pigments—chlorophyll a, chlorophyll b, total chlorophyll (a+b), and carotenoids—play a crucial role in light absorption, and changes in their concentrations directly influence photosynthetic efficiency. The enzyme **Rubisco** (*ribulose-1,5-bisphosphate carboxylase/oxygenase*) is central to the carbon fixation process in photosynthesis. Under flooding conditions, Rubisco activity typically declines, impairing photosynthetic performance. Therefore, maintaining or enhancing Rubisco activity is essential for sustaining carbon assimilation during waterlogging (Pan et al., 2021).

B.2.2. Respiratory Adaptation

Under waterlogging stress, reduced oxygen availability inhibits mitochondrial respiration and leads to a significant decline in **a**denosine triphosphate (ATP) production. To compensate, plants increase anaerobic metabolic pathways such as glycolysis and ethanol fermentation to meet the minimal ATP requirements for cellular maintenance.In the absence of oxygen, the activities of enzymes such as pyruvate decarboxylase (PDC), alcohol dehydrogenase (ADH), and lactate dehydrogenase (LDH) are upregulated to support continued ATP synthesis. PDC catalyzes the initial step in fermentation, converting pyruvate into acetaldehyde, which is then further processed to ethanol by ADH.It converts pyruvate into acetaldehyde. Afterwards Alcohol dehydrogenase (ADH) then converts acetaldehyde to ethanol (Pyruvate $\xrightarrow{PDC}$ Acetaldeyde $\xrightarrow{ADH}$ Ethanol) (Figure 6). This conversion regenerates **NAD^+**, allowing glycolysis to proceed under anaerobic conditions and enabling the cell to continue producing limited amounts of ATP (Pan et al., 2021). While aerobic respiration yields approximately 36 ATP molecules per one molecule of glucose, only 2 ATP molecules are generated through anaerobic fermentation pathways. Despite this low energy yield, it is crucial for maintaining essential metabolic functions and ensuring the short-term survival of the plant under waterlogged conditions (Lamsfus-Prieto et al., 2016; Aslam et al., 2023).

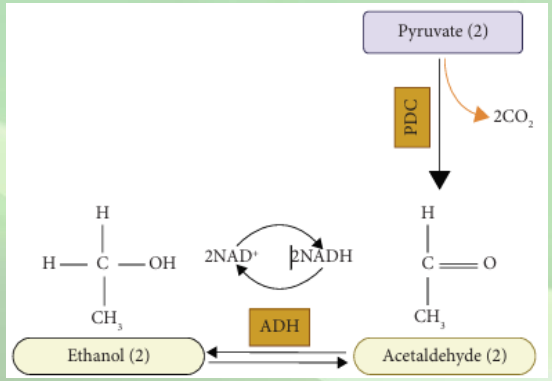


Fig 6. Metabolic pathway of ethanol metabolism in waterlogging (PDC: pyruvate decarboxylase; ADH: alcohol dehydrogenase) (Ali et al., 2023).

B.2.3.Antioxidant Resistance System

Under waterlogging stress, plants activate their antioxidant defense system to prevent cellular damage caused by the accumulation of reactive oxygen species (ROS). This system comprises both enzymatic and non-enzymatic components. Enzymatic antioxidants include superoxide dismutase (SOD), catalase (CAT), peroxidase (POD),

ascorbate peroxidase (APX), dehydroascorbate reductase (DHAR), monodehydroascorbate reductase (MDHAR), and glutathione reductase (GR). Non-enzymatic antioxidants consist of ascorbic acid (AA), glutathione (GSH), tocopherols (lipid-soluble), and carotenoids (Figure 7) (Manghwar et al., 2024).In addition, plants accumulate osmoprotectants such as proline, soluble sugars, free amino acids, and soluble proteins to counteract the toxic effects of waterlogging (Aslam et al., 2023). Yin et al. (2009) compared the physiological and biochemical responses of flood-tolerant and flood-sensitive *Chrysanthemum* cultivars under waterlogging stress. They reported that the activities of alcohol dehydrogenase (ADH), pyruvate decarboxylase (PDC), and lactate dehydrogenase (LDH) increased in both cultivars, with a greater increase observed in the flood-sensitive one. In contrast, the activities of SOD, APX, and POD were significantly higher in the flood-tolerant cultivar, indicating a more effective antioxidant defense system.

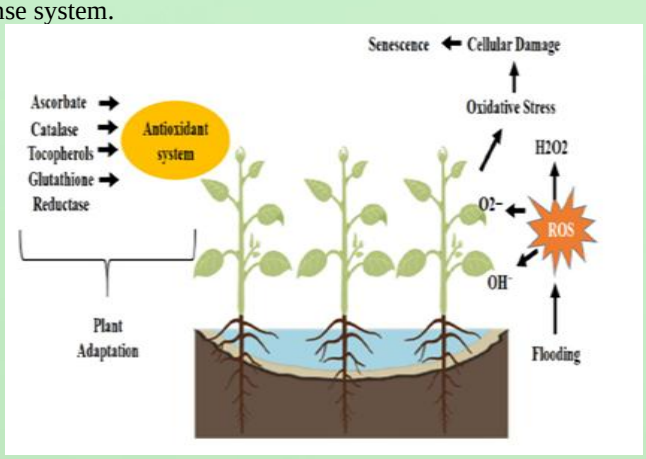


Fig 7. Reactive oxygen species (ROS) production and antioxidant enzyme activity under waterlogging conditions (Nasrullah Ali et al., 2022).

B.3. Resistance Mechanism Induced by Plant Hormones or Biostimulants

Plant hormones, which play key roles in growth and development, also contribute significantly to waterlogging tolerance. A schematic representation of the effects of plant growth regulators under waterlogging conditions is provided in Figure 8.

Ethylene accumulates under waterlogging stress but also regulates several physiological processes that facilitate adaptation. For instance, its interaction with auxin (IAA) promotes the formation of adventitious roots (ARs) (Aslam et al., 2023). Although waterlogging leads to substantial carbohydrate consumption and energy deficiency, light-supported photosynthesis continues to supply sugars that assist auxin transport and AR formation in the hypocotyl (Pan et al., 2021). Furthermore, ethylene interacts with gibberellin (GA_3) to stimulate stem elongation in wetland species (Pan et al., 2025). In a study on different soybean genotypes, GA content was found to be higher in waterlogging-tolerant lines compared to sensitive ones (Pan et al., 2021).

Abscisic acid (ABA) levels increase under waterlogging, activating the antioxidant defense system and inducing stomatal closure. This helps reduce oxidative damage, delay senescence, and enhance waterlogging tolerance. However, in plants exposed to prolonged submergence, ABA levels tend to decrease due to elevated gibberellin activity (Pan et al., 2021).

Although research on melatonin and flood stress is still limited, existing studies indicate that melatonin can enhance tolerance by stimulating antioxidant enzyme activity, reducing ROS levels, and supporting normal growth (Huo et al., 2022). Melatonin application has also been shown to mitigate the effects of anaerobic respiration and reduce MDA and ROS-induced chlorosis (Pan et al., 2021).

Brassinosteroids (BRs) are plant-derived steroids that enhance tolerance to waterlogging by promoting the translocation of carbohydrates from leaves to roots, increasing antioxidant enzyme activity, and reducing ROS production (Pan et al., 2021).

Salicylic acid (SA), a common phenolic compound, enhances plant adaptation to stress by modulating antioxidant pathways (Pan et al., 2021). These hormones reduce ROS accumulation, regulate proline levels, and improve stress tolerance (Hasanuzzaman et al., 2022).

Jasmonic acid (JA) is another growth regulator; however, its role in waterlogging tolerance is less well understood. In a study conducted on soybean, JA application improved flood tolerance by increasing phenolic compounds, flavonoids, and sugar content (Manghwar et al., 2024).

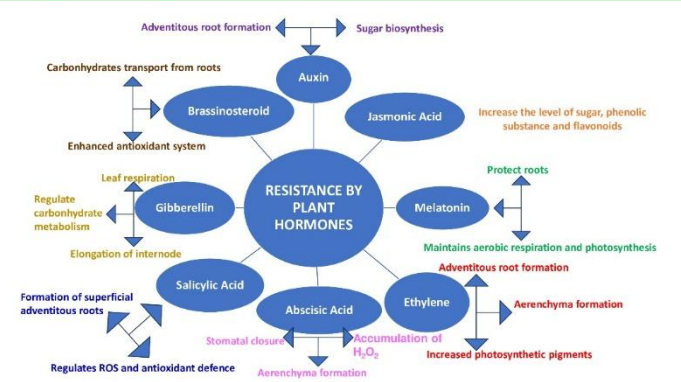


Fig 8. Schematic representation of hormonal resistance mechanisms in plants against waterlogging stress (Manghwar et al., 2024- changed)

B.4.Molecular approaches and breeding

In recent years, molecular techniques have increasingly been employed to assess plant tolerance to abiotic stress factors. The identification of novel genes and proteins is crucial for understanding plant responses to waterlogging stress (Manghwar et al., 2024). Genes associated with flood tolerance can be utilized in genetic modification, gene silencing, and overexpression strategies, thereby forming the basis for molecular breeding programs aimed at improving flood tolerance in horticultural crops (Pan et al., 2025).

Numerous studies have demonstrated that various genes exhibit significant responses to waterlogging stress. For instance, ethylene response factor (ERF) proteins play a critical role in regulating plant responses to environmental stresses. Additionally, the WRKY transcription factor family, one of the largest families in plants, has been shown to be involved in both biotic and abiotic stress responses.

Although chrysanthemum (*Chrysanthemum spp.*) is one of the most economically important ornamental plants, it is relatively sensitive to waterlogging. As a result, it has become one of the most extensively studied ornamental species with regard to flooding tolerance. Several transcription factors and genes, particularly from the AP2/ERF family, have been implicated in waterlogging response pathways in chrysanthemum. In another genetic study, the SOS1 gene was shown to enhance waterlogging tolerance in chrysanthemum (Manghwar et al., 2024).

Furthermore, Su et al. identified single nucleotide polymorphism (SNP) loci associated with waterlogging tolerance in chrysanthemum and developed derived cleaved amplified polymorphic sequences (dCAPS) markers based on PCR technology for SNP detection (Pan et al., 2025).

In petunia, plants carrying the PhERF2 gene demonstrated increased flooding tolerance and faster recovery following submergence (Yin et al., 2019). Other ornamental species that have been investigated for their waterlogging tolerance mechanisms include *Prunus cerasifera*, *Populus* spp., *Iris pseudacorus*, *Begonia* spp., and *Tropaeolum majus* (Pan et al., 2025).

There is a great need to develop flood-tolerant plant varieties, especially in the face of increasing instances of waterlogging stress (Sharma et al., 2021). Recent advances include the development of two double haploid line (DHL) populations through crosses between submergence-tolerant and submergence-sensitive rice cultivars (Ahmad et al., 2013). These DHL populations offer valuable genetic material for identifying loci associated with flood tolerance and accelerating breeding efforts through molecular and classical selection approaches.

C. Researches on Ornamental Plants Againist Waterlogging and Applications in Urban Landscape

Flood stress primarily affects landscape plants by reducing their ornamental value. Pan et al. (2025) identified 50 flood-tolerant plant species with high ornamental potential, including 27 herbaceous plants (*Alternanthera philoxeroides, Hedychium coronarium, Hydrocotyle verticillata, Ophiopogon bodinieri, Dianella ensifolia, Phormium tenax, Zinnia angustifolia, Echeveria cuspidata, Cladium mariscus, Carex secta, Schenoplectus scirpoides, Melilotus sulcatus, Melilotus indicus, Sesbania virgata, Iris tectorum, Stachys byzantina, Salvia officinalis, Thamnochortus insignis, Scirpus tabernaemontani, Angelonia salicariifolia, Zizania latifolia, Phragmites mauritianus, Fimbristylis sinensis, Elymus nutans, Typha orientalis, Canna spp., Alpinia zerumbet*), 7 shrubs (*Ruellia brittoniana, Calotropis procera, Cistus creticus, Jatropha curcas, Pteris ensiformis, Lavandula angustifolia, Myricaria laxiflora*), and 15 tree species (*Alnus spp., Casuarina obesa, Leucaena leucocephala, Dalbergia odorifera, Acacia auriculiformis, Dalbergia sissoo, Pterocarya stenoptera, Ficus altissima, Eucalyptus camaldulensis, Cleistocalyx operculatus, Prunus padus, Prunus cerasus, Populus alba, Populus deltoides, Tamarix chinensis*).

Yang et al. (2020) applied 10 days of waterlogging followed by 7 days of recovery to *Zinnia angustifolia*, *Angelonia salicariifolia*, *Celosia argentea*, and *Melampodium paludosum*. The effects of control and waterlogging treatments on these species are illustrated in Figure 9.



Fig 9. Effects of waterlogging on the performances of *Angelonia salicaliifolia*, *Zinnia angustifolia*, *Celosia argentea* and *Melampodium paludosum* plants. CK: Control WL: Well irrigated condition (60%soil moisture) (Yang et al., 2020).

Plants were subjected to 36 days of waterlogging followed by 12 days of recovery in a study comparing waterlogging-tolerant (*Sedum spectabile* 'Carl') and waterlogging-sensitive (*Sedum spectabile* 'Rosenteller') cultivars (Figure 10).In conclusion, *S. spectabile* 'Carl' demonstrated the ability to withstand waterlogging stress for up to 36 days and exhibited a superior recovery capacity following soil drainage when compared to *S. spectabile* 'Rosenteller'. The ability to form adventitious roots significantly contributed to recovery after stress and adaptation to prolonged waterlogging.Additionally, researchers reported that the improved waterlogging tolerance of *S. spectabile* 'Carl' may be closely associated with a more effective antioxidant enzyme system, including superoxide dismutase (SOD), catalase (CAT), and ascorbate peroxidase (APX), which help to mitigate oxidative stress caused by ROS (Zhang et al., 2019).



Fig 10. Morphological responses of waterlogging-tolerant *Sedum spectabile* 'Carl' and susceptible *S. spectabile* 'Rosenteller' cultivars. Water saturated for 0, 7, 14, 21, 28 and 36 days and *S. spectabile* 'Carl' treated for 12 days (C0, C7, C14, C21, C28, C36 and RC12) and *S. spectabile* 'Rosenteller' treated on the same days (R0, R7, R14, R21, R28, R36 and RR12) (Zhang et al., 2019).

In recent years, with global climate change, a concept known as "Sponge City" has begun to be implemented in many urban areas around the world. This concept refers to a set of green architectural and ecological strategies designed to absorb and retain excess rainwater—much like a sponge—rather than draining it quickly during periods of heavy rainfall (Figure 11). This approach has proven to be highly effective in improving urban flood resilience, and plant selection plays a critical role in the successful design and functionality of sponge cities (Pan et al., 2025).

One key component of sponge cities is the use of rain gardens, which are vegetated depressions that collect and infiltrate stormwater. Francini et al. (2022) described several plant species suitable for use in rain gardens, grouped as follows:

- Trees: *Metasequoia glyptostroboides* Hu & W.C. Cheng, *Salix babylonica* L., *Paulownia tomentosa* Steud., *Acer palmatum* Thunb. 'Atropurpureum'
- Shrubs: *Fatsia japonica* Decne. & Planch., *Aucuba japonica* Thunb. 'Variegata', *Loropetalum chinense* Oliv.
- Medicinal and herbaceous plants: *Hemerocallis fulva* (L.) L., *Farfugium japonicum* (L.) Kitam., *Stipa tenuissima* Trin.
- Aquatic or wetland plants: *Phragmites australis* (Cav.) Steud., *Gladiolus gandavensis* Van Houtte, *Iris pseudacorus* L., *Iris tectorum* Maxim., *Lythrum salicaria* L., *Cyperus alternifolius* L.

These species contribute not only to flood mitigation and water regulation but also enhance the aesthetic and ecological value of urban green spaces

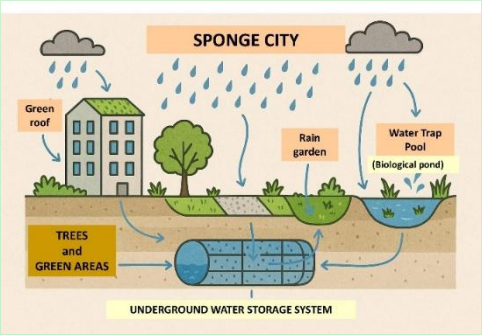


Fig 11. Sponge City Concept

Conclusions

This study provides valuable insights for the selection of ornamental plants suited for flood-prone areas by identifying species and cultivars with demonstrated waterlogging tolerance.

In addition to increased research on advanced breeding approaches for improving waterlogging resistance, further studies are needed to elucidate the molecular mechanisms of stress tolerance in ornamental plants. Therefore, future research should focus on both molecular and applied aspects of waterlogging resistance and aim to translate promising findings into practical applications in urban landscape design and planning.

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Water resources management and climate change in South Sudan

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Abstract

South Sudan, one of the least developed countries, is vulnerable to the socioeconomic losses and damages caused by climate change since its people rely on climate-sensitive natural resources for survival. Given the country's recurring droughts, promoting water collection and storage for varied purposes is a high priority. Water availability may be directly affected by poor water quality. This study focuses on how climate change has altered water supplies to assist South Sudan's future water usage and highlights the potential for future research to make a significant impact. The findings of this study will be necessary for future Nile River research, a field that holds great promise. In South Sudan, the quantity and quality of water have dropped during the last two decades. The article also shows how droughts are becoming more frequent, and rivers and streams are shrinking due to climate change. Several once-permanent rivers now have seasonal flows. South Sudan is especially vulnerable to the effects of climate change due to poor infrastructure, several developmental obstacles caused by the protracted civil war, and the fact that 95% of the population relies on climate-sensitive natural resources, particularly rain-fed subsistence agriculture, and total reliance on forests as a source of energy and other environmental goods and services.

Introduction

The impact of climate change on water resources is a pressing concern for both science and policy, particularly as global warming continues to dominate global concerns. According to a 1997 UN report on global freshwater resources, one-third of the world's population lived in countries facing water stress, using more than 20% of their available water supplies. The report predicted that by 2025, up to two-thirds of the global population would live in areas with water shortages (Jubek et al., 2019). However, the effects of climate change on water resources can vary significantly by region. Some areas may experience water shortages, dramatically increasing the number of people at risk due to rising consumption. Conversely, in coastal areas, rising sea levels threaten the lives and livelihoods of millions. Droughts and floods are expected to become more frequent in many parts of the world, leading to increased poverty and hunger, higher economic costs, and potential crop losses. These impacts must be assessed with precise spatial and temporal data to enable long-term water resource planning in light of climate change, a crucial aspect that this research aims to address (Abbaspour et al., 2009).

Water is one of the nation's most valuable natural resources, essential for agricultural production and human life (Albut et al., 2018; Bağdatlı et al., 2024). Climate and water systems are closely linked: climate change affects water availability and usage. Generally, higher temperatures increase water usage, especially for irrigation, while higher precipitation reduces use. However, there is yet to be a definitive historical link between water usage trends and climate, mainly due to limited data and the influence of non-climatic factors (IPCC, 2007). Regional climate models suggest that rising temperatures and reduced rainfall will cause significant declines in water resources.

In South Sudan, water resources are unevenly distributed geographically and seasonally. The country's water availability is highly variable due to frequent severe floods and droughts. Most of the country lies within the Nile River basin, where water is stored in floodplains, ponds, rivers, and wetlands. With low population density and limited industrial development, current water demand remains low, but it is expected to rise sharply with population growth and economic development. In 2007, the Ministry of Water Resources and Irrigation raised concerns about human activities' growing impact on water availability and quality, noting decreasing water tables, reduced river flows, and increased pollution in urban areas (MWRI, 2007).

Water is a naturally renewable resource, continuously circulating through the environment. Water resource assessments must prioritize water flow, although stored water in natural and artificial reservoirs increases availability for human use. The climate system limits the flow rate of renewable freshwater resources (RFWR). While global water withdrawals are currently well below the upper limit, over two billion people live in regions of extreme water stress due to the uneven distribution of RFWR across time and geography. Climate change is expected to accelerate the water cycle, potentially increasing RFWR. This could reduce the number of people experiencing water stress, but changes in seasonal patterns and the likelihood of extreme events may offset these benefits. Reducing current vulnerabilities will be the first step in preparing for these anticipated changes (Jubek et al., 2019).

While water has historically been a source of conflict, it can also provide opportunities for cooperation and peace. In Sudan, effective management of water resources is seen as a pathway to sustainable development and stability. With proper institutions and legal frameworks, water resources can significantly contribute to the country's economic, social, and environmental progress (UNEP, 2020). Studies on climate change in Sudan and South Sudan have mainly focused on temperature and precipitation, the two key climate variables and extreme events (Nasreldin & Elsheikh, 2022; Elsheikh et al., 2022a). Thus, this study aims to assess the effects of climate change on South Sudan's water resources.

Water Resources and climate change in South Sudan

South Sudan, a landlocked country occupying 96% of the Nile River Basin in East-Central Africa, shares borders with Sudan to the north, Ethiopia and Kenya to the east, Uganda and the Democratic Republic of the Congo to the south, and the Central African Republic to the west. Positioned between latitudes 3.5° and 12° North and longitudes 24° to 36° East, it spans 658,842 km². Vast grasslands, wetlands, and tropical forests dominate the landscape. The country's natural resources include significant agricultural, mineral, water, wildlife, forestry, and energy assets (Jubek et al., 2019). South Sudan has one of the lowest population densities in sub-Saharan Africa, with fewer than 13 people per square kilometre. In the arid northern regions, livelihoods are primarily based on seasonal agriculture, pastoralism, fishing, and hunting, while the wooded savannas in central South Sudan offer diverse livelihood opportunities. The country is divided into three regions—Bahr el Ghazal, Equatoria, and Greater Upper Nile—and was initially organised into ten states, which have since increased to thirty-two (MWRI, 2016).

Water availability in upstream and downstream regions of transboundary river basins is a sensitive issue. South Sudan's location in the middle of the Nile Basin, between downstream countries like Egypt, Ethiopia, and Sudan, and upstream Nile Equatorial countries such as Burundi, Kenya, and Uganda, means that its water quality and quantity are influenced by water retention, withdrawals, and development activities in these neighbouring states (Fernando & Garvey, 2013). Through floods and groundwater flow, lateral water transfers move water between surplus and deficit areas. However, monitoring water flows throughout the Nile Basin is challenging due to variations in how each country and sector measures water data, such as withdrawals, stocks, and wastewater return flows. Earth observation data provide insight into the basin's main water flows and fluxes (Bastiaanssen et al., 2014).

Water usage in the Nile Basin threatens its ability to meet future demand, especially for South Sudan. Over 80% of the water withdrawn from the basin is used for irrigated agriculture. South Sudan's water withdrawal remains low relative to other Nile Basin countries (Jubek et al., 2019). Before 2011, Sudan's total water withdrawal was estimated to be around 27,590 million m³, with agriculture accounting for 26,150 million m³. Post-2011, South Sudan's annual water withdrawal is estimated to be about 658 million m³, or 1.3% of its total renewable water resource, with agriculture still using the majority (FAO, 2016; MWRI, 2016).

As water resources become increasingly strained due to societal demands, understanding climate change's effects on the water cycle is crucial for managing this resource. Water management strategies, such as operational adjustments, demand management, and infrastructural changes, must be considered to adapt to climate change. Resource supply, system demands, and performance requirements will likely shift due to climate impacts, requiring diverse strategies and preferences for adaptation (Levi et al., 2009; Elsheikh et al., 2023; Elsheikh et al., 2024). Cooperation between regions that share water resources is critical for improving management. However, climate change and rising water demand may exacerbate conflicts over water, mainly where unilateral actions to address shortages could increase competition. Changes in land productivity could also result in new agricultural systems, potentially leading to environmental stress, including soil erosion and biodiversity loss (Meier et al., 2007).

In South Sudan, where surface water resources may become increasingly inaccessible, the demand for groundwater will likely rise, particularly as irrigation agriculture expands to meet the growing population's food demands. Although irrigation remains limited, effective water resource management and accurate demand projections ensure the country's stability (Jubek et al., 2019). South Sudan's water resource management strategies aim to improve water resource mapping, evaluation, and monitoring capabilities, enhance the water information system, and promote sustainable management and conflict prevention (MWRI, 2016). National governments, particularly in less developed countries, must implement key water management measures to address the effects of climate change on water resources. This includes identifying areas at risk of shortages, promoting the construction of water harvesting infrastructure, improving water and sanitation facilities in urban areas, and developing supplemental irrigation systems in rural areas to increase food security. Additionally, establishing legal frameworks to penalise water pollution and manage waste effectively is essential (Wada & Bierkens, 2014; Jubek et al., 2019).

Since 1970, global surface air temperatures have significantly increased. Independent research teams have processed data from various sources, showing a consistent warming trend supported by the melting of Arctic sea ice, glacier retreat, and other indicators (Elsheikh et al., 2022b). As climate change continues, droughts and floods are expected to become more frequent, with precipitation patterns increasingly concentrated in heavy events. This

uneven distribution of rainfall, influenced by topography and atmospheric circulation, is already altering precipitation patterns globally, including in South Sudan (Elsheikh, 2021a; Bağdatlı et al., 2023).

In South Sudan, subsistence agriculture, which depends on rain-fed farming and traditional methods, forms the economic backbone for 78% of households. This makes the country highly vulnerable to climate change, particularly irregular rainfall. Droughts and floods threaten livestock, crop production, and natural habitats, while flash floods damage low-lying forests near wetlands and rivers (Jubek et al., 2019). Global action is required to mitigate the effects of climate change, including reducing carbon emissions and preventing global warming (Elsheikh, 2021b). South Sudan's Sudd wetland, vital in regulating regional weather patterns, is particularly vulnerable to these changes. Effective water resource management in South Sudan is crucial to mitigate the impacts of climate change, ensure sustainable development, and prevent conflicts over water.

Conclusion

The Republic of South Sudan needs to strengthen environmental health infrastructure to prevent the spread of water-borne diseases, significantly as climate change worsens water quality and availability. The rising population and increasing demand for water will further strain the country's water resources in the coming years. The pressure on these resources will be unevenly distributed globally, with some regions, including South Sudan, feeling the impact more acutely and urgently. Climate change can either exacerbate or alleviate stress on water resources, depending on various factors such as climate scenarios, water demand, and the quality and quantity of available water.

Water quantity and quality in South Sudan have declined significantly over the past two decades. Rivers that once flowed year-round are now seasonal, and the reduction in water flow has led to increased siltation, particularly in downstream areas where sediment accumulates. Urban water quality has deteriorated due to the direct discharge of municipal wastewater, sewage, and industrial effluents into water bodies. The lack of adequate wastewater and sanitation management has resulted in widespread contamination, contributing to repeated outbreaks of gastrointestinal diseases and posing additional threats to already stressed water resources. To mitigate these issues, South Sudan must prioritise upgrading water and sanitation infrastructure, improving wastewater management, and implementing strategies to adapt to the effects of climate change on water availability and quality. Proper management will be crucial to safeguarding public health and ensuring a sustainable water supply in the face of growing environmental challenges.

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Biodegradable Materials Production from Food Waste: A Sustainable Approach

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Abstract

Food waste has become a significant global issue, contributing to environmental degradation through methane emissions in landfills. This research explores the potential of utilizing food waste as a source for producing biodegradable materials, offering a sustainable alternative to petroleum-based plastics. By examining various studies and advancements in this area, the research discusses the potential benefits, challenges, and future prospects of converting food waste into eco-friendly products. Food waste is a critical issue worldwide, with approximately one-third of food produced for human consumption being discarded. This waste, often sent to landfills, decomposes anaerobically, generating methane, a potent greenhouse gas. To mitigate the environmental impacts of food waste, innovative solutions are being explored, including converting it into biodegradable materials. This approach not only addresses the problem of waste disposal but also provides an alternative to conventional plastics, which are derived from non-renewable resources and contribute to long-term environmental pollution.

Keywords:

ID: 350

Enhancing Poultry Nutrition with Hydrobarothermal-Treated Non-GMO Soybean Meal: A Sustainable Approach

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Abstract

The European Union faces significant challenges in ensuring protein security, particularly in the livestock sector. To address this issue, Agrolok sp. z o.o. has developed an innovative high-protein feed component derived from Polish non-GMO soybeans. This study focuses on optimizing the processing conditions of soybeans through hydrobarothermal treatment (HBT) to enhance protein content, digestibility, and amino acid availability. The treated soybean meal was evaluated for its nutritional benefits in poultry diets, with a focus on growth performance, feed efficiency, and nutrient utilization. Preliminary results demonstrate that HBT significantly improves the protein quality of soybean meal by reducing anti-nutritional factors and increasing the bioavailability of essential amino acids. Poultry fed with HBT-treated soybean meal exhibited superior weight gain, feed conversion ratios, and overall nutrient absorption compared to those fed with conventionally processed soybean meal. These findings highlight the potential of HBT-treated non-GMO soybean meal as a sustainable and efficient protein source for poultry nutrition. By enhancing the nutritional profile of SBM, this approach not only supports animal health and performance but also aligns with consumer preferences for non-GMO and sustainable feed ingredients. The improved feed efficiency and reduced environmental impact further emphasize the economic and ecological benefits of this technology. Future research will focus on scaling up the production process and conducting long-term trials to validate these findings. This project represents a significant step toward meeting the protein needs of the livestock industry while promoting sustainable agricultural practices in the EU.

Key Words: *SBM, Amino Acids, Sustainable, Poultry Nutrition, Processing Technology*

Introduction

Protein security remains a critical challenge for the European Union (EU), particularly in livestock and poultry production, where the demand for high-quality, sustainable protein sources continues to rise. Soybean meal (SBM) is the most widely used protein ingredient in poultry diets due to its high crude protein content, favorable amino acid profile, and excellent digestibility (Asghar et al., 2024). However, the EU's heavy reliance on imported, genetically modified (GM) soybean accounting for 80–95% of plant protein-rich feed materials has raised environmental, health, and socio-economic concerns (Gil et al., 2024). These include the extensive use of herbicides such as glyphosate, risks of gene transfer, potential allergenicity, and consolidation of GM seed ownership among a few multinational corporations (Aderibigbe et al., 2020). Moreover, the EU is only 3% self-sufficient in soybean and SBM production, making this reliance unsustainable and vulnerable to market volatility (Chisoro et al., 2025). As a result, there is growing interest in increasing the cultivation and processing of locally grown, non-GMO soybeans to reduce dependency on imports and enhance feed sustainability.

Traditional soybean processing methods, particularly hexane-based solvent extraction, present additional sustainability challenges (Preece et al., 2017). These conventional techniques are not only energy-intensive but also involve hazardous chemicals, while often failing to adequately reduce anti-nutritional factors that impair poultry nutrient absorption (Chisoro et al., 2025). The resulting protein quality limitations contribute to feed inefficiencies, with feed costs representing 60-70% of total poultry production expenses (Asghar et al., 2021,2022; Rauw et al., 2023). This economic burden, combined with increasing environmental regulations under the EU Green Deal, necessitates innovative solutions for protein production and processing.

In response to this challenge, Agrolok sp. z o.o. has developed an innovative solution using hydrobarothermal treatment (HBT) to process Polish non-GMO soybeans. HBT is a thermal and pressure-based technique that improves the nutritional quality of soybean meal by reducing anti-nutritional factors (ANFs), enhancing protein digestibility, and increasing the bioavailability of essential amino acids (Asghar et al., 2024; Chojnacka et al., 2021). Unlike conventional hexane-based solvent extraction, which is energy-intensive, hazardous, and

environmentally unfriendly, HBT offers a safer and more sustainable alternative (Sakkas et al., 2019). Preliminary studies have demonstrated that poultry fed with HBT-treated SBM show improved growth performance, feed conversion ratios, and nutrient absorption compared to those consuming traditionally processed SBM. Additionally, HBT-SBM contributes to environmental sustainability by lowering nitrogen excretion and supporting more efficient nitrogen utilization in poultry (Asghar et al., 2024; Zhu, et al., 2023). Hydrobarothermal treatment (HBT) has emerged as a transformative technology for processing European-grown non-GMO soybeans. Developed by Agrolok sp. z o.o., this method utilizes controlled heat and pressure to significantly enhance the nutritional quality of soybean meal (Orlich et al., 2023). Compared to conventional processing, HBT achieves superior reduction of anti-nutritional factors (90-95% trypsin inhibitor inactivation) while better preserving essential amino acids (>95% lysine retention) (Deng and Kim 2024). Feeding trials demonstrate that poultry receiving HBT-treated soybean meal show 5-8% improved growth performance and feed conversion ratios, along with enhanced gut health markers ((Asghar et al., 2024; Chojnacka et al., 2021).

The adoption of HBT technology offers multiple strategic benefits for the EU:

- Enhanced feed security through utilization of domestically grown non-GMO soybeans
- Improved sustainability with 20-25% lower carbon footprint compared to imported soybean meal
- Economic advantages through better feed efficiency and potential for regional processing
- Alignment with policy goals under the Farm to Fork Strategy and European Green Deal

Small-to-medium scale decentralized processing using HBT could particularly benefit EU agriculture by:

- Reducing transportation emissions through local production
- Creating new value chains for European soybean growers
- Providing premium, traceable feed ingredients for poultry producers

As the EU transitions toward more sustainable agricultural practices, technologies like HBT represent crucial tools for developing resilient, environmentally responsible protein supplies (Orlich et al., 2023). Their implementation supports not only improved poultry nutrition and farm economics but also broader objectives of food sovereignty and climate-smart agriculture in Europe.

Given that feed costs constitute 60–70% of total poultry production expenses (Asghar et al., 2021,2022; Naimati et al. 2022) improving feed efficiency through innovative processing can significantly benefit producers economically (Akram et al., 2019, 2021). This is particularly important as the EU shifts toward more environmentally responsible and welfare-conscious farming practices. Furthermore, small- to medium-scale decentralized processing of non-GMO soybeans could empower regional agriculture, reduce logistics-related emissions, and promote protein self-sufficiency (Woźniak et al., 2019). This review aims to provide a comprehensive analysis of the role of HBT-treated non-GMO soybean meal in enhancing poultry nutrition, with a focus on its nutritional, functional, environmental, and economic implications. It also addresses the broader significance of adopting sustainable soybean processing technologies to meet the EU's protein demands while aligning with evolving agricultural and consumer standards.

The EU Protein Deficit and Its Implications for Sustainable Poultry Nutrition

The European Union faces a critical protein deficit, importing over 70% of its protein-rich feed ingredients, primarily soybean meal, from non-EU sources, mainly Brazil, Argentina, and the United States (Sierżant et al., 2023; Sepngang et al., 2020). This heavy dependence creates substantial vulnerabilities in supply chain stability, economic sustainability, and environmental compliance. Recent global crises have exposed the fragility of long-distance protein supply chains, while the EU's annual expenditure on protein imports exceeds €10 billion (Rotundo et al., 2024). Furthermore, approximately 60-70% of imported soy has been linked to deforestation risks in South America (Song et al., 2021), conflicting with growing consumer demand for GMO-free animal products and stricter sustainability requirements under the EU Green Deal (McMichael 2021). Currently, EU soybean production meets only about 8% of domestic demand due to agronomic limitations in northern member states, yield disparities compared to major exporting countries, and competition for arable land with higher-value crops (Sajid et al., 2023; Sepngang et al., 2020). This protein gap affects the entire agri-food value chain, reducing the competitiveness of EU livestock farming due to feed cost volatility, limiting innovation potential in feed formulation, and creating challenges in meeting consumer demands for traceable, sustainable animal products. The Farm to Fork Strategy (Pío Beltrán et al., 2022) aims to address this deficit by reducing reliance on imported plant proteins by 2030, increasing cultivation of EU protein crops by 25%, and improving sustainability of livestock production systems. Achieving these goals requires overcoming significant technical and economic barriers through development of high-yielding, climate-resilient soybean varieties, implementation of advanced processing technologies like hydrobarothermal treatment, and creation of supportive policy frameworks and market incentives to enhance the viability of European-grown protein crops as competitive alternatives to imported feedstuffs (Asghar et al., 2024).

The Need for Advanced Processing Techniques for European Non-GMO Soybeans in Poultry Nutrition

The European Union's transition toward protein self-sufficiency through domestic non-GMO soybean production requires advanced processing technologies to overcome the limitations of conventional methods. Traditional techniques such as thermal toasting (100-130°C) and mechanical extrusion (130-180°C) demonstrate insufficient efficacy, achieving only 60-80% reduction of trypsin inhibitors while causing 15-25% loss of heat-sensitive amino acids through Maillard reactions (Abdollahi et al., 2022). These methods also leave 40-50% of lectins and 30-40% of oligosaccharides intact, compromising protein quality and gut health in poultry (Norozi et al., 2022).

These limitations necessitate the development of advanced processing technologies that maximize nutritional value while minimizing undesirable effects. Hydrobarothermal treatment (HBT), which integrates controlled heat, moisture, and pressure, has emerged as a superior alternative, offering more efficient ANF inactivation, enhanced protein solubility, and improved amino acid preservation compared to traditional methods (Asghar et al., 2024). By optimizing these parameters, HBT can transform European non-GMO soybeans into a high-quality, locally sourced protein supplement for poultry diets, aligning with both nutritional efficiency and sustainability goals. The adoption of such innovative processing techniques is critical not only for improving feed formulations but also for supporting the EU's transition toward a more resilient, self-sufficient, and environmentally responsible livestock industry. Hydrobarothermal treatment (HBT) has emerged as a technologically superior solution, employing precisely controlled parameters (110-150°C, 3-10 bar pressure, 15-30% moisture) to achieve 90-95% ANF inactivation while preserving >95% of essential amino acids (Orlich et al., 2023). This advanced processing method demonstrates three key advantages over conventional approaches: (1) superior protein digestibility (90-92% vs 82-85%), (2) complete inactivation of trypsin inhibitors (>90% vs 60-80%), and (3) significant reduction of oligosaccharides (70-75% vs 30-40%) (Asghar et al., 2024; Pope et al., 2023). The limitations of conventional processing become particularly evident when examining the nutritional composition of processed soybean products. Standard thermal treatments typically achieve only partial inactivation of trypsin inhibitors (60-80% reduction), while simultaneously causing 15-25% loss of heat-sensitive amino acids (Andrade et al., 2016). Furthermore, these methods often fail to adequately address other ANFs such as lectins and oligosaccharides, which can negatively impact gut health and nutrient absorption in poultry (Avilés-Gaxiola et al., 2018). The resulting suboptimal protein quality directly affects feed conversion ratios and growth performance, ultimately compromising the economic viability of poultry operations.

Field trials confirm these technical benefits translate to measurable performance improvements, including 5-8% better feed conversion ratios and 7-10% enhanced amino acid utilization in poultry (Zampiga et al., 2021).

The implementation of HBT technology aligns with critical EU strategic objectives by:

- Enhancing nutritional efficiency through improved protein quality
- Reducing the carbon footprint of poultry feed by 20-25%
- Decreasing soybean import dependence by 30-40% (Chojnacka et al., 2021)

The transition to advanced processing technologies does present certain challenges that must be addressed. Initial capital investments for specialized equipment can be substantial, and the industry requires standardized protocols to ensure consistent product quality across processing facilities. Additionally, comprehensive life cycle assessments are needed to fully evaluate the environmental benefits compared to conventional methods. However, the long-term advantages in terms of improved feed efficiency, reduced environmental impact, and enhanced food security justify these investments and warrant policy support for technology adoption. Current adoption faces several challenges including high capital expenditure (€2.5-3.5 million for industrial-scale systems) and pending EFSA approval under Novel Feed regulations (expected 2025). However, pilot plants in France and Poland demonstrate promising 12-18 month return on investment periods through improved feed efficiency.

Future research should focus on:

- Developing hybrid HBT-enzymatic processing systems
- Optimizing parameters for different soybean varieties
- Establishing standardized quality protocols
- Conducting comprehensive life cycle assessments

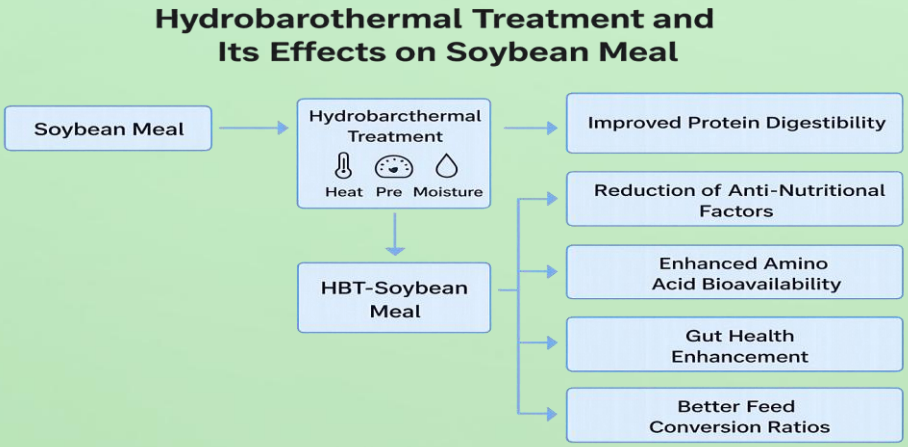
With appropriate policy support under CAP 2023-2027, HBT technology has the potential to transform 30-40% of EU poultry feed protein supply by 2030, simultaneously addressing nutritional, environmental, and food security challenges while meeting growing consumer demand for sustainable, non-GMO animal products.

Future research directions should focus on optimizing processing parameters for different poultry production systems, developing hybrid technologies that combine HBT with enzymatic treatments, and establishing clear quality standards for processed protein ingredients. The integration of these advanced processing methods with precision feeding systems could further enhance their effectiveness, contributing to the development of more sustainable and efficient poultry production systems in the EU.

Hydrobarothermal Treatment and Its Effects on Soybean Meal in Poultry Nutrition

Hydrobarothermal (HBT) treatment represents a significant advancement in feed processing technology, employing controlled heat (110-150°C), pressure (3-10 bar), and moisture (15-30%) to optimize the nutritional quality of soybean meal (SBM) (Kopacz et al., 2021). This innovative process achieves superior inactivation of anti-nutritional factors (ANFs), reducing trypsin inhibitors by 90-95% and lectins by 85-90%, while conventional methods typically only achieve 70-85% and 60-75% reduction respectively (Asghar et al., 2024). The enhanced protein modification during HBT processing improves crude protein digestibility to 90-92%, compared to 82-85% in conventionally processed SBM, with particularly notable retention (>95%) of critical amino acids like lysine and methionine (Sakkas et al., 2019).

The nutritional advantages of HBT-treated SBM translate directly to improved poultry performance metrics. Broilers fed HBT-SBM demonstrate 5-8% greater weight gain (2.5kg vs 2.3kg final weight) and 3-5% better feed conversion ratios (1.45 vs 1.55) (Boroojeni et al., 2016). In layers, these benefits manifest as 2-3% higher egg production and 5-7% improved shell strength due to enhanced mineral absorption. The technology's impact on gut health is particularly significant, with HBT-fed birds showing 25-30% lower intestinal inflammation markers and 15-20% greater villi surface area, leading to more efficient nutrient absorption (Asghar et al., 2024; Cowieson et al., 2020).



From an environmental perspective, HBT processing contributes to sustainable poultry production by improving nitrogen utilization efficiency by 10-15%, thereby reducing nitrogen excretion in manure by 20-25%. When combined with regional non-GMO soybean sourcing, the technology can decrease the carbon footprint of poultry feed by 30-40% compared to imported conventional SBM (Beltranena and Zijlstra 2022). These advantages align with multiple EU policy objectives, including the Farm to Fork Strategy's goals for sustainable protein sources and the European Green Deal's climate targets (Chojnacka et al., 2021).

The economic viability of HBT-SBM is demonstrated by breakeven analyses showing the 8-10% price premium is offset within 12-18 months through improved feed efficiency and production outcomes (Rauw et al., 2023). As the poultry industry seeks solutions that combine nutritional excellence with environmental responsibility, HBT-treated SBM emerges as a technologically advanced feed ingredient capable of addressing contemporary challenges in animal nutrition, sustainability, and food security.

Sustainability and Non-GMO Advantages of Hydrobarothermal-Treated Soybean Meal

The adoption of hydrobarothermal-treated non-GMO soybean meal (HBT-SBM) in poultry nutrition presents significant sustainability and health benefits, aligning with global trends toward environmentally responsible and health-conscious food production. Non-GMO soybeans are increasingly preferred in the EU market due to growing consumer concerns about the potential ecological and health impacts of genetically modified crops (Bürgin 2023). Cultivation of non-GMO varieties supports agricultural biodiversity by minimizing risks of gene flow to wild relatives and reducing dependence on broad-spectrum herbicides like glyphosate, which have been linked to ecosystem disruption and potential human health risks (Leinonen et al., 2013). From an environmental perspective, HBT processing enhances the nutritional efficiency of soybean meal by improving protein digestibility (90-92% vs 82-85% in conventional SBM) and amino acid bioavailability, which translates to better feed conversion ratios (1.45 vs 1.55) and reduced nitrogen excretion in poultry waste (Lu et al., 2017). This nutritional optimization contributes to a 20-25% lower carbon footprint per kg of poultry produced compared to conventional soybean-based diets (Ma et al., 2019). Furthermore, regional sourcing of non-GMO soybeans reduces reliance on imported feed ingredients, decreasing transportation-related emissions by an estimated 30-40% while strengthening local agricultural economies (Basnet et al., 2023). The combination of non-GMO status with HBT technology supports multiple EU policy objectives, including the Farm to Fork Strategy's goals for sustainable food systems, the European Green Deal's climate targets, and the Organic Action Plan's emphasis on natural production methods

(Kassim et al., 2020). These synergistic benefits position HBT-SBM as a comprehensive solution addressing contemporary challenges in poultry nutrition, including environmental sustainability, feed efficiency, and consumer demand for clean-label animal products.

Comparative Performance with Conventional Soybean Meal

Hydrobarothermally-treated soybean meal (HBT-SBM) demonstrates superior nutritional and performance characteristics compared to conventional soybean meal (CSBM) in poultry diets. While traditional solvent extraction methods effectively remove oil, they often leave residual anti-nutritional factors (ANFs) including trypsin inhibitors (15-20% remaining) and lectins (10-15% remaining) that impair nutrient absorption (Chojnacka et al., 2021). In contrast, HBT processing achieves 90-95% reduction of these ANFs while preserving >95% of heat-sensitive amino acids like lysine (Wang et al. 2023). This technological advantage translates to measurable performance benefits: broilers fed HBT-SBM show 5-8% higher weight gain (2.5kg vs 2.3kg final weight) and improved feed conversion ratios (1.45 vs 1.55) due to enhanced protein digestibility (90-92% vs 82-85% for CSBM). The superior nutrient profile of HBT-SBM supports better muscle development and feathering, while gut health metrics reveal 25-30% lower inflammatory markers and 15-20% greater villi surface area (Rysman et al. 2023). Layer performance shows parallel improvements, with 2-3% higher egg production and 5-7% stronger eggshells attributed to enhanced mineral absorption (Qiao et al. 2015). Economic analyses confirm these zootechnical advantages offset HBT-SBM's 8-10% price premium within 12-18 months of adoption (Rauw et al., 2023). Furthermore, life cycle assessments demonstrate HBT-SBM reduces the carbon footprint of poultry production by 20-25% compared to CSBM-based diets (European Commission, 2009). These comprehensive benefits establish HBT-SBM as a nutritionally, economically, and environmentally superior alternative to conventional soybean meal in modern poultry production systems.

Challenges and Future Perspectives of Hydrobarothermal Treatment for EU Poultry Nutrition

The implementation of hydrobarothermal treatment (HBT) for non-GMO soybean processing in EU poultry nutrition presents both significant opportunities and challenges that must be addressed for successful adoption. From a technical perspective, the process requires precise control of temperature (110-150°C) and pressure (3-10 bar) parameters, as minor deviations can reduce anti-nutritional factor (ANF) inactivation efficiency by 15-20% (Asghar et al., 2024). The substantial capital expenditure for industrial-scale HBT reactors, estimated at 40-60% higher than conventional extruders, creates economic barriers particularly for small producers (Chojnacka et al., 2021). Current market analyses indicate HBT-processed soybean meal commands a €50-70/ton premium over traditional products, with return on investment periods exceeding 3-5 years without subsidies (Eurostat, 2024). Regulatory hurdles further complicate adoption, as EFSA certification under EU Regulation 2015/2283 typically requires 24-36 months, while strict 0.9% GMO contamination thresholds impose additional quality control challenges.

Scalability remains a critical limitation, as existing infrastructure may not support widespread commercial production, particularly in regions lacking medium or small-scale processing facilities (Srai et al., 2016). The need for technical expertise and the high initial investment create implementation barriers, especially for smallholders (Lee and Gambiza 2022). While preliminary studies show promising results, comprehensive long-term trials are needed to validate consistent performance benefits across different poultry breeds and production systems (Asghar et al., 2024).

Future research should prioritize several key areas: development of hybrid technologies combining HBT with enzymatic pre-treatments to enhance phosphorus bioavailability by 30-40% (Asghar et al., 2024), implementation of AI-controlled systems to optimize processing parameters (Chojnacka et al., 2021), and detailed nutritional studies on HBT's effects on poultry gut microbiomes. The potential for amino acid fortification through co-processing with alternative protein sources like insect meal deserves exploration (EU Horizon PROTEIN2Food project). From a sustainability perspective, developing life cycle assessment protocols to quantify HBT's 20-30% lower carbon footprint compared to imported soybean meal is crucial (IPCC Tier 2 methodology), along with valorization strategies for byproducts like wastewater-to-biogas conversion (15m³ CH4/ton waste in pilot studies). Policy interventions will be critical for overcoming these barriers. Potential measures include CAP reforms for equipment subsidies, reduced VAT schemes for poultry products using EU-processed soybean meal (modeled after French "Label Rouge"), and establishment of public-private research consortia through initiatives like EIT Food to accelerate commercial scaling (target: 50+ HBT plants by 2030). With coordinated efforts across technical, economic, and regulatory dimensions, HBT technology could achieve 30% market penetration for EU poultry feed by 2030 (Delgado et al., 2023), significantly enhancing the bloc's protein self-sufficiency while meeting sustainability goals. The growing demand for eco-friendly feed ingredients and advances in processing technology create favorable conditions for HBT adoption, provided that challenges in cost reduction, energy efficiency, and regulatory compliance can be successfully addressed through continued research and policy support.

Conclusion

Hydrobarothermal-treated non-GMO soybean meal (HBT-SBM) represents a significant advancement in sustainable poultry nutrition, offering enhanced protein digestibility, reduced anti-nutritional factors, and improved amino acid bioavailability. This innovative processing method aligns with the growing demand for non-GMO, environmentally responsible feed ingredients while also addressing the European Union's protein security concerns. Compared to conventional soybean meal, HBT-SBM delivers superior growth performance, feed efficiency, and gut health benefits in poultry, making it a valuable alternative in modern feed formulations. Although challenges such as production scalability and economic feasibility persist, ongoing research and technological development are expected to overcome these barriers. As the industry continues to shift toward more sustainable and transparent food systems, HBT-SBM stands out as a promising solution that supports animal health, environmental stewardship, and consumer trust.

Hydrobarothermal-treated non-GMO soybean meal presents a sustainable and effective alternative for enhancing poultry nutrition. Its ability to improve protein digestibility, promote gut health, and support better feed efficiency makes it a promising solution for the poultry industry. Further research and industry adoption will determine its potential in large-scale poultry production systems.

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ID: 352

Niğde Patates Ekim Alanlarında Bulunan Solanum spp. (Köpek Üzümü) Biyotiplerinin Metribuzin Kullanımına Bağlı Dayanıklılık Mekanizmaları

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Özet

Metribuzin, triazinon kimyasal ailesine ait bir herbisittir. Patates ekim alanlarında yabancı ot mücadelesinde çıkış öncesi ve çıkış sonrası olarak uygulanmaktadır. Metribuzin etki mekanizmasını, fotosistem II'de bulunan D1 proteinine bağlanarak fotosentez için gerekli olan elektron transferini durdurarak fotosentezi engelleme şeklinde ve hedef bitkilerde oksidatif stres oluşturarak ölüme yol açarak gösterir. Ancak bazı yabancı ot türleri, uzun süreli herbisit kullanımına bağlı olarak farklı dayanıklılık mekanizmaları geliştirebilir. Ancak patates ile aynı familyadan olan *Solanum spp.* (Köpek Üzümü) türü yabancı otların mücadelesinde giderek artan bir şekilde çoğu durumda etkili olmamakta ve Türkiye'de önemli ürün kayıplarına neden olmaktadır.

Bu çalışmada; Niğde patates ekim alanlarında bulunan Köpek Üzümü popülasyonlarının metribuzine karşı dayanıklılık nedenleri araştırılmıştır. Patates ekim alanlarından toplanan dayanıklı köpek üzümü popülasyonlarının metribuzin toleransının nedenleri, metribuzinin kök ve yapraklar yoluyla bitki bünyesine alınımı, hedef bölge olan yapraklara kadar taşınımı, bitkilerin farklı organlarda metabolizasyonu(detoksifikasyonu) incelenmiştir.

İlk aşamada patates ekim alanlarından dayanıklılık şüphesi tespit edilen 4, karşılaştırma amaçlı olarak metribuzine hiçbir şekilde maruz kalmamış patates ekim alanları dışından hassas 1 popülasyon laboratuvar şartlarında sıcaklık ve nem kontrollü basitleştirilmiş sistemlerde incelenmiştir.

Farklı biyotiplerin metribuzin toleransı, metribuzin adsorpsiyon kapasiteleri, molekülün bitkilerin toprak üstü kısımlarına transfer hızları, metribuzinin hedef bölgesi olan yapraklar ve diğer bitki kısımlarındaki metribuzin konsantrasyonları ve metabolitleri belirlenerek değerlendirildi. Farklı organlardaki metabolizma hızı ve ortaya çıkan metabolitler daha ayrıntılı olarak belirlenmiştir. Bu çalışma ^{14}C-metribuzin (^{14}C ile işaretlenmiş radyoaktif metribuzin) kullanılarak çeşitli radyometrik yöntemlerden (Farklı ekstraksiyon metotları, Radio-HPLC (radyokromatografisi), otoradyografi, oxidizer vb.) faydalanılmıştır.

Uzun yıllar boyunca devamlı olarak metribuzin uygulaması yapılmış patates ekim alanlarından elde edilen dayanıklılık şüphesi olan biyotipler, ekilmemiş topraklardan elde edilen biyotiplere göre metribuzine daha fazla tolerans göstermektedir. *Solanum nigrum* türlerinin metribuzini kökten alım kapasitesi yoğun olup, hedef organlara transferi yüksektir. Bu davranış, bu molekülün güçlü hidrofilitesine (Kow = 1.6) bağlıdır. Ancak otoradyografik çalışmalar bitkideki metribuzin kalıntılarının kompartmanlaştığını ve radyoaktivitenin iletken dokularda tutulduğunu göstermektedir. Hedef doku düzeyinde metribuzin konsantrasyonu için elde edilen değerler, çalışılan biyotiplere bağlı olarak çok farklıdır, yaprak düzeyinde kritik konsantrasyonda belirgin farklılıklar vardır.

Köklerden alınan metribuzinin, birkaç gün içinde hızlı bir şekilde metabolize edildiği tespit edilmiştir. Bundan dolayı gövde ve yapraklardaki metribuzin konsantrasyonu oldukça düşüktür. Bitkilerin kökleri ve toprak üstü dokularında metribuzinin metabolizasyonu sonucu ortaya çıkan metabolitlerde farklılıklar görülmektedir. Köklerde çeşitli hidrofilik konjuge kalıntıların yanında birçok lipofilik metabolitlerin ortaya çıktığı; yapraklarda ise yalnızca konjuge kalıntıların bulunduğu belirlenmiştir.

Sonuç olarak; patates ekim alanlarında bulunan biyotiplerin toleransı, metribuzinin asıl hedef bölgesi olan kloroplastlara taşınma kapasitelerinin düşük olmasıyla ilişkili olabilir. Bu durum bir yandan herbisitin kök seviyesindeki çok aktif detoksifikasyon kapasitesine diğer yandan ise kök ve gövde ayrışması (vasküler dokularda tutulma) için eşit derecede dikkate değer bir potansiyele sahip olmasına bağlanabilir; bu sayede aktif maddenin bu kloroplastlara transferi büyük ölçüde azaltılabilmektedir.

Tüm bu sonuçlar değerlendirildiğinde metribuzinin çıkış sonrası uygulamaları, metribuzinin asıl hedef bölgesi olan yapraklara (Kloroplastlar) ulaşmasını ve sadece yaprak penetrasyonu yoluyla uygulama dozunun tamamının bitki bünyesine alınmasını kolaylaştırabilir. Böylece kökler ve iletim demetlerince tutulma ve metabolizasyon aşamalarını atlatarak daha etkili olabilir.

Anahtar kelimeler: *Patates, metribuzin, Solanum spp., dayanıklılık, tolerans detoksifikasyon, transfer.*

ID: 353

Nohut'ta (Cicer arietinum L.) metribuzinin metabolizasyonu ve transferi

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Özet

Yabancı ot kontrolü nohut *(Cicer arietinum* L.) üretimindeki en önemli kısıtlamalardan biri olmaya devam etmektedir. Türkiye'de nohut ekim alanlarındaki yabancı otları yabancı otları kontrol altına almak için tamamen seçici herbisit sayısı çok azdır ve bu herbisitlerin birçoğu ithal ve pahalıdır. Dahası üreticilerin uygulama zamanı ve dozlarında yaptıkları hatalardan dolayı nohutta fitotoksisite hasarlarına sıklıkla rastlanmakta ve ciddi verim kayıpları ortaya çıkmaktadır. 2020 yılından bu yana, bir triazinon herbisiti olan metribuzin, Türkiye'de nohut ekim alanlarında görülen çeşitli tek ve çift çenekli yabancı otların kontrolü için, 140 ml/da dozda, çıkış öncesi uygulamalar için tescil edilmiştir. Bu çalışmanın amacı; nohutun metribuzine karşı toleransının temellerini belirlemek ve bitki bünyesinde metribuzine karşı verdiği farklı tepkimeleri ölçmektir. Çıkış öncesi uygulamalar sonucu nohut'un metribuzini adsorpsiyon kapasitesi, bitkilerin toprak üstü kısımlarına transfer hızı, metribuzinin hedef bölgesi olan yapraklar ve diğer bitki kısımlarındaki metribuzin konsantrasyonları ve metabolitleri belirlenerek değerlendirilmiştir. Farklı organlardaki metabolizasyon hızları ve ortaya çıkan metabolitler daha ayrıntılı olarak belirlenmiştir. Bu çalışma ^{14}C-metribuzin (^{14}C ile işaretlenmiş radyoaktif metribuzin) kullanılarak çeşitli radyometrik yöntemlerden (farklı ekstraksiyon metotları, Radio-HPLC (radyokromatografisi), otoradyografi, oxidizer vb.) faydalanılmıştır. Metribuzin toleransı, kökler tarafından emilimi ve metabolizasyonu çalışmalarında Fransız kökenli Kabuli bir varyete olan TWIST çeşidi ısı ve nem kontrollü bitki büyütme kabinlerinde basitleştirilmiş sistemlerde incelenmiştir. Metribuzinin kökler ve kotiledonlar tarafından emilim kapasitesi, toprak üstü kısımlara transfer hızı, gövde ve hedef bölge olan yapraklardaki metribuzin konsantrasyonları bitkiyi farklı organlara ayırarak her organ için metribuzinin konsantrasyonu belirlenmiştir. İkinci aşamada ise farklı organlardaki metabolizasyon aşamaları incelenmiştir. Bu analizler ^{14}C-metribuzin kullanılarak ve çeşitli radyometrik yöntemler (R-HPLC (radyokromatografisi, oksidizer, phosporimager vb.) kullanılarak gerçekleştirilmiştir. Yapılan analizler; metribuzinin kökler aracılığıyla yoğun bir şekilde bitki bünyesine alındığını, metribuzinin yapraklara kadar taşındığını göstermektedir. R-HPLC analizleri sonucunda, uygulamadan 21 gün sonra kök, gövde ve yapraklarda çok sayıda farklı metribuzin metabolitleri tespit edilmiştir. Yapraklarda metribuzin ve metabolitlerinin konsantrasyonları oldukça farklılık göstermektedir. Genç yapraklarda yaşlı yapraklara göre daha fazla radyoaktivite birikimi olmaktadır. Nohutun metribuzin toleransının temelinde, kloroplastlara taşınma hızının kapasite düşük olması ve farklı yollarla yüksek detoksifikasyon kapasitesine sahip olmasıyla ilişkilendirilebilir, bu sayede aktif maddenin kloroplastlara transferi büyük ölçüde azaltılarak hedef bölgedeki metribuzin konsantrasyon kritik değerine ulaşması engellenmektedir.

Anahtar Kelimeler: *Metribuzin, Nohut, Cicer arietinum, seçicilik, tolerans, metabolizasyon, detoksifikasyon.*

ID: 355

Biyobozunur Ambalajların Gıdalarda Kullanımı

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Özet

Biyobozunur ambalaj malzemeleri, plastik ambalajlara kıyasla kullanım ömürlerini tamamladıktan sonra doğaya karışarak çevre kirliliğini önleyen ve geride doğaya zararlı, zehirli maddeler bırakmayan materyallerdir. Biyobozunurluk, bir malzemenin mikroorganizmalar tarafından üretilen enzimlerle parçalanarak karbondioksit, metan, su, inorganik bileşikler ve biyokütle gibi daha basit maddelere dönüşebilmesini ifade eder. Bu dönüşüm, çevreye zarar vermeden doğal yollarla gerçekleşir. Petrol türevli sentetik ambalaj malzemeleri ise doğada uzun süre bozulmadıkları için çevre kirliliğine ve toksik madde birikimine yol açmaktadır. Bu malzemelerden kaynaklanan atıklar, çevre sorunlarını da beraberinde getirmektedir. Bu nedenle, artan çevre sorunlarını önlemek amacıyla, sentetik ambalaj malzemelerine alternatif olarak biyobozunur gıda ambalaj malzemelerinin kullanımı giderek artmaktadır. Bu malzemelerin üretiminde nişasta, selüloz, protein gibi doğal kaynaklar kullanılır. Biyobozunur plastikler, polisakkaritler, proteinler, lipitler ve polyester gibi yenilenebilir tarımsal kaynaklardan üretilebilir. Selüloz ve nişasta, doğada bolca bulunduğundan biyoplastik üretiminde önemli bir rol oynar. Protein bazlı malzemeler, polimer zincirleri arasında güçlü bağlar oluşturarak yapıyı daha dayanıklı hale getirir. Ancak, bu malzemelerin esneklik kazanması için plastikleştirici eklenmesi gerekir. Biyobazlı ve biyobozunur plastikler, yenilenebilir kaynaklardan üretilen ve aynı zamanda doğada biyolojik olarak ayrışabilen plastik türleridir. Bu durum hem çevre dostu üretim süreçleri hem de kullanım sonrası minimum çevresel etki sağlama açısından büyük bir avantaj sunar. Bu derleme ile, biyobozunur ambalajların fiziksel ve kimyasal özelliklerinin belirlenmesi ve aynı zamanda gıdalarda kullanım potansiyeli değerlendirilecektir.

Anahtar Kelimeler: *Gıda Ambalajlama, Biyobozunur, Fermentasyon, Petrol Türevleri, Atık*

ID: 357

Integrative Genomic and Transcriptomic Analysis of GASA Gene family in Sunflower Reveals Their Regulatory Role in Drought Stress Response

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Abstract

Climate change has an outstanding impact on world agriculture. It increases both the frequency and severity of drought, reducing crop yield and compromising food security. Sunflower (*Helianthus annuus*), being a valuable oilseed crop suffers considerably by drought sress. Therefore, it is imperative to determine the genetic component that regulates its tolerance in water deficit environments in order to facilitate the production of drought-tolerant cultivars. *The GASA (Gibberellic Acid-Stimulated Arabidopsis)* gene family is known to be involved in hormone signaling, stress adaptation and growth regulation, but it's functional characterization lacks in sunflower. In the current study, we employed an integrative approach to screen and characterize the *GASA* gene family in sunflower and their roles under drought stress. Genome-wide analysis identified 27members of *HaGASA* gene family, unevenly distributed on eleven chromosomes. Phylogenetic analysis grouped the genes into five subfamilies supported by conserved motifs and structural homology with Arabidopsis, peanut, and soybean *GASA* genes. Analysis of cis-regulatory elements revealed drought and stress-responsive element enrichment with hormone and growth-related regulatory motifs. Based on transcriptomic data in the NCBI database, *HaGASA* gene expression in ten genotypes of sunflower was screened under drought. Fourteen genes exhibited differential expression under stress indicating a significant role in drought tolerance. Organ-specific expression analysis revealed *HaGASA2, HaGASA11, HaGASA17, HaGASA19, HaGASA21,* and *HaGASA26* to be dominantly expressed in the stem. This study emphasizes the *HaGASA* gene family's role in improving sunflower drought stress tolerance as well as gives preliminary insight into the genetic and regulatory processes of *HaGASA* genes that could help breed drought-tolerant sunflower varieties.

Keywords: *GASA, expression analysis, sunflower, drought*

ID: 358

Determination of Quality Characteristics of Cracked Wheat (Dövme) Obtained From Different Wheat Verieties

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Abstract

Cracked wheat is a traditional cereal product obtained from wheat grains that have been soaked and hulled. It holds a significant place in Anatolian cuisine and is particularly used in dishes such as keşkek, soups, pilafs, and salads. Due to its content of B vitamins, iron, and protein, it is considered a nutritious food source. This study aims to determine the quality characteristics of cracked wheat produced from different wheat varieties. Initially, the study focuses on identifying the quality parameters of cracked wheat. Additionally, another objective is to determine the wheat varieties most suitable for cracked wheat production. In the literature, there are numerous studies on raw material quality for various wheat-based products. However, there is a lack of detailed research on the quality characteristics of cracked wheat, which is widely used in Turkey, and on the raw material properties suitable for its production. Therefore, this study aims to contribute to the literature by providing research findings on cracked wheat production. In the study, different wheat varieties named Zivago, Bayraktar-2000, and Cumhuriyet-75 were used. These wheat varieties were processed into cracked wheat using traditional methods in a local mill. Various analyses were conducted on both the raw wheat and the obtained cracked wheat. The analyses performed on the wheat included moisture, ash, protein, total fat, hectoliter weight, thousand kernel weight, hardness, and color measurements. Meanwhile, the analyses conducted on the cracked wheat included color, hardness, cooking time, dry matter loss during cooking, starch release into water, bulk density, and sensory evaluations. Processing the wheat into cracked wheat resulted in a moisture increase of 1-4% across all varieties. For cracked wheat obtained from hard wheat, an increase in L* and b* values and a decrease in a* value were observed. Conversely, cracked wheat obtained from soft wheat exhibited a decrease in L*, a*, and b* values. According to cooking time analysis results, cracked wheat from hard wheat varieties cooked faster than those from soft wheat varieties. The dry matter loss in cracked wheat derived from hard wheat was found to be higher than that from soft wheat. The dry matter loss during cooking followed the order Bayraktar-2000 > Cumhuriyet-75 > Zivago. Finally, sensory evaluation results indicated that the Zivago variety received the highest scores in the taste parameter, Bayraktar-2000 was rated highest in external appearance, and Zivago again received the highest scores in overall acceptance. The cracked wheat sample from the Cumhuriyet-75 variety received the lowest scores in sensory tests.

Key Words: *Wheat, Cracked wheat (dovme), Hard wheat, Soft wheat, Cracked wheat (dovme) quality*

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ID: 359

Antibacterial Effects of Imported (New Zealand) and Local Algerian Honeys Based on Botanical Origin

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Abstract

The overuse of antibiotics in agriculture and veterinary medicine poses significant risks to public health and the environment. Honey, known for its natural antibacterial properties, presents a potential alternative. This study evaluates the antibacterial activity of honeys based on their botanical origin. Pollen analysis was conducted following the classical method of Louveaux et al. (1978) to identify pollen grains. Physicochemical parameters (pH, moisture, hydroxymethylfurfural (HMF), and conductivity) were assessed according to Codex Alimentarius (2001) guidelines. Antibacterial activity was determined using agar diffusion assays. The analysis identified one polyfloral and five monofloral honeys from three botanical sources (*Citrus, Eucalyptus, Jujube*). Two samples were classified as honeydew honey. Most samples met quality standards regarding pH, moisture, and conductivity. Among bacterial strains, *Staphylococcus aureus* exhibited the highest sensitivity, with inhibition zones of 36.84 ± 5.52 mm for undiluted honey, decreasing to 22.92 ± 6.01 mm at a 12.5% dilution. *Escherichia coli* and *Klebsiella pneumoniae* showed slightly higher resistance, with inhibition zones ranging from 34.48 ± 4.03 mm to 21.36 ± 3.54 mm for *E. coli* and 34.68 ± 4.32 mm to 22.88 ± 4.25 mm for *K. pneumoniae*. Manuka honey and honeydew honey exhibited the strongest antibacterial activity, particularly at higher concentrations. These findings highlight the potential of honey as a natural alternative for treating bacterial infections, especially in light of rising antibiotic resistance. Manuka and honeydew honeys show promising therapeutic properties, warranting further research into their antibacterial mechanisms and medical applications.

Key Words:

ID: 360

Postprocessing microflora of commercial *soumbara* (a fermented nere seeds product) produced in Côte d'Ivoire.

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Abstract

Soumbara is a fermented food condiment obtained by fermentation of nere seeds (*Parkia biglobosa*). Soumbara, like all traditional food condiments, once produced is sold in informal markets where hygiene conditions are not respected. The objective of this study was to identify microbiological hazards in soumbara sold on the market in Abidjan in order to ensure the health safety of consumers. For this study, 375 samples of soumbara were analyzed. Microbiological analyses focused on the search for spoilage and pathogenic germs as well as the search and quantification of mycotoxins. The results showed that the loads of mesophilic aerobic germs varied from $(3.1\pm0.9).10^5$ CFU/g to $(5.3\pm0.3)10^6$ CFU/g. As for the *Staphylococcus aureus* load, it varied from $(1.0\pm0.3)10^4$ CFU/g to $(3.2\pm0.5)10^5$ CFU/g. For molds, the load ranged from $(1.2\pm0.1)10^3$ CFU/g to $(4.8\pm0.2)10^3$ CFU/g. *Bacillus spores* ranged from $(1.9\pm0.7)10^4$ CFU/g to $(9.9\pm0.8)10^4$ CFU/g. *Staphylococcus* loads in soumbara were higher than the maximum acceptable value 100 CFU/g, standard 2005/2073/EC. In the analyzed samples aflatoxins and Zearelanone were detected. The results of mycotoxins detected in soumbara were below the standard EC/1881/2006. *Aspergilus, Fusarium, Penicelium* and *Stachybotrys, Mucor, Rhizopus, Bacillus cereus, Bacillus spp, Bacillus subtilis, Staphylococcus aureus, Staphylococcus spp, Bacillus anthracis* were detected in the samples analyzed. All samples analyzed did not contain *Escherichia coli, Clostridium perfringens* and *Salmonella spp*. Consumption of soumbara sold on the market could constitute a danger for the consumer.

***Keywords**: soumbara, microbiological quality, market, mycotoxins*

ID: 362

Evaluation of ensiled brewery spent grain as a substitute for protein source concentrate in the diet of Lactating crossbred dairy cows at Adami Tullu Agricultural Research Center

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Abstract

Feeding different substitution levels of Noug seed cake with ensiled brewery spent grain on milk yield and milk composition of crossbred dairy animals and its net benefit was done at Adami Tulu Agricultural Research Center on Ten early lactating crossbred dairy cows (HF with Arsi) with an average daily milk yield of 5.04 liter and 272.5 kg body weight were selected from nucleus herd at dairy farm. They were randomly assigned to 5 x 2 Latin Square Design composed of five dietary treatments. Each period being split to 15 days of adaptation and 15 days of measurement. The experiment was conducted from January 2024 to June 2024. Concentrate feed Noug seed cake and Wheat bran was purchased from Adama suppliers and brewery spent grain was purchased from nearby local suppliers. Brewery spent grain was allowed to cool under aerated shade for 24 hrs then manually pressed and packed into airtight plastic drum without any preservatives. Rhodes grass hay produced at on station was used as basal diet. The substitution has four levels and compared with previously recommended ration for lactating crossbred cows. The dietary treatments were T1= 66 % wheat bran + 33 NSC + 1% salt (Control), T2= 66 % wheat bran + 24.75 NSC+8.25 BSG + 1% salt, T3= 66 % wheat bran + 16.5 NSC+16.5 BSG + 1% salt, T4= 66 % wheat bran + 8.25 NSC+24.75 BSG + 1% salt and T5= 66 % wheat bran + 33 BSG + 1% salt. Daily feed offered and refused, milk yield and body weight change per 15 days, milk composition at initial and end of each feeding period were collected. The result reveals that the total dry matter intake and body weight gain doesn't differ among the treatments. The milk yield and composition of lactating animals fed feeds with varying amounts of brewery spent grain did not differ significantly. The highest net benefit was obtained from animals fed on dietary treatment 5(100%) replacement of Noug seed cake by ensiled brewery spent grain which was 272.4 ETB/cow/day. Dietary treatment 5 (wheat bran + Brewery spent grain+ salt) was recommended for further evaluation and intervention at on farm level for dairy producers who kept crossbred cows and have access for brewery spent grain especially for urban and peri urban dairy producers.

Key words: *Brewery spent gain, early lactating, crossbred cows, net benefit*

Introduction

In Ethiopia, the major constraint for low productivity of dairy cows is the shortage of livestock feeds in terms of quantity and quality, especially during the dry season (Ahmed *et al.*, 2010). Agro-industrial by-products such as flour mill and oil extracting factories by-products have been widely used as energy and protein supplements in ruminant ration (FAO, 2012).

The rising cost of agro-industrial by-products, especially oil seed cakes such as groundnut and noug seed cake made it less reliable (Goswami *et al.*, 2013). Therefore, it is imperative to search for cheap, nutritious and easily available non-conventional feed resources.

With the increasing cost of concentrate feeds and growing demand for dairy products, alternative feedstuffs have become a great necessity in the dairy industry. Due to the rapid expansion of brewery factories and their environmentally friend nature, brewery by-products have become an option for dairy managers looking for alternative feedstuffs (Bell *et al*, 2012).

In Ethiopia, there were 12 beer factories producing an estimated 26,722.8 tons brewery spent grains (SBGs) on DM basis and 360,758.1 hectoliter (hl) of brewery spent yeast (BSY) in 2016 that can be used as animal feed (Amare, 2016). It was reported by Alvarez Aranguiz *et al*. (2019) that the BSG produced can be enough to feed 60,000 cows with 10 kg/day throughout the year. The average price of spent brewery grain is still very attractive compared with other available feed (Alvarez Aranguiz *et al*., 2019).

Wet brewery grain is a good source of protein with a crude protein content that ranges from 25 to 34% (Thomas *et al.*, 2016). The protein is mainly placed in the germ portion of the spent grain and is digested to a partial amount in the rumen and to a greater amount in the small intestinal tract. The concentration of rumen degradable protein ranges from 28-43% (mean 35%), indicating that wet brewery grains are good sources of rumen un-degradable, or "bypass-protein" and it has 20-32 % dry matter (Thomas *et al.*, 2016). Feeding wet brewery spent grain to dairy

cows is a worthwhile opportunity for dairy farmers to offer additional rumen un-degradable protein and energy to dairy cows, with equal or enhanced milk production (Zanton, 2016).

Ensiling of wet brewery grain either alone or along with other feed is ecologically and economically feasible, and easily applicable from a technological viewpoint to dairy farmers in Ethiopia. The selection of the right conservation method is crucial for storing and utilizing this feed without spoilage.

In Ethiopia most of previous studies done on wet BSG mainly focus on mechanism of extending shelf life but the rate at which the feed to be included in the ration of dairy cattle not yet studied (Alvarez Aranguiz *et al*. 2019; Getu, 2019). The study was conducted to address the following objectives:

Objectives

- To evaluate the effect of feeding different substitution levels of Noug seed cake with ensiled brewery spent grain on milk yield and milk composition of crossbred dairy animals
- To evaluate the net benefit of feeding different substitution level of ensiled brewery spent grain in the ration of crossbred dairy animals

Materials and methods

Description of the study area

The study was conducted at Adami Tulu Agricultural Research center located at 167km south of Addis Ababa at latitude of 70 9' N and 3807'E longitude in semi-arid middle rift valley of Ethiopia. The area is situated 1500 meters above sea level and the soil type of the area is fine, sandy loam with sand, clay in the proportion of 34:48:18 respectively. The average annual rainfall is 760mm. The minimum and maximum temperature are 12.6 and 27^0c, respectively (ATARC, 2003).

Experimental feed preparation

The concentrate mix was prepared based on the recommendation of dairy animals' nutrient requirement (Kearl, 1982; ARC, 2001). The concentrate mix was formulated to furnish 12 MJ of energy per kg of feed and to contain 20 % total protein. Furthermore, feed provision was adjusted fortnightly depending on milk production of the animals. As wheat bran is the most common source of energy and sustainably available, it was used as a source of energy while noug cake was used as protein source. The roughages were provided ad libitum adjusted to 10% refusal daily from the previous day offer on a DM basis. Studies in Ethiopia have revealed that the daily concentrate allowance can be calculated at the rate of 0.5 kg/liter of milk and can be offered twice a day in the morning and afternoon hours. Water was available free of choice.

Brewery spent grain Ensiling/preserving methods used:

Simple ensiling methods were used. Brewery spent grain was ensiled alone. Fresh brewery spent grain was acquired from local suppliers and stored under shade for 24hrs at room temperature which allows to cool brewery spent grain. After 24hr brewery spent grain were stored in airtight plastic drum. A quintal of brewery spent grain divided into three portions and compressed manually by using human labor into 400-liter plastic water drum to keep airtight and the procedure repeated until the drum filled at its full capacity. We took daily the amount required and kept closed the plastic drum.

Feed offered and refusals were measured and recorded for each cow daily to determine the dry matter as a difference between the offered and refused feed for both silage, roughage and concentrate mix. Body weight measurements were taken for each dietary treatment over two consecutive days at the beginning and end of each period using weighing scale. The animals were made to fast overnight and body weight measurements were taken at 06:00A.M before feed and water being served to the animals. The cows were hand-milked twice a day in the morning and afternoon at (6:00 am and 6:00Pm) and milk yield will be measured using graduated plastic cylinder and recorded for each animal.

Experimental design and animal management

Ten early lactating crossbred dairy cows (Holstein Frisian with Arsi) with an average daily milk yield of 5.04 liter and 272.5 kg average body weight were selected from ATARC dairy farm. All experimental animals were treated for internal and external parasites before feeding started. Animals were assigned to one of the dietary treatments randomly. They were randomly blocked in 5 x 2 Latin Square Design composed of five dietary treatments. Each period being split to 15 days of adaptation and 15 days of measurement. The experiment was conducted from January 2024 to June 2024. The cows were individually stall-fed in well-ventilated houses/barns with well dried floors and appropriate drainage slope and gutters.

Milk composition analysis

Milk composition was analyzed by collecting milk samples at initial and at end of each feeding period. Milk samples (100 ml) from the morning and evening milking were collected in sterile plastic containers. Composite samples were used for analysis of milk composition. Milk sample was analyzed by using a Lactoscan milk analyzer for milk fat, protein, lactose total solids and pH.

Chemical composition of experimental ingredients used

Table 1. Chemical composition (% DM) and metabolizable energy (MJ/kg DM) contents of experimental feed ingredients

Feeds offered	DM	OM	CP	NDF	ADF	Lignin	ME (MJ Kg^{-1} DM)
Noug seed cake	92.2	89.08	32.1	34.7	26.7	7	9.5
Brewery spent grain	94.1	93	26.9	63.2	24	5	10.3
Wheat bran	90.5	95.7	17	38.2	9.4	2.54	11.7

Treatments

T1= 66 % wheat bran + 33 NSC + 1% salt (Control)
T2= 66 % wheat bran + 24.75 NSC+8.25 BSG + 1% salt
T3= 66 % wheat bran + 16.5 NSC+16.5 BSG + 1% salt
T4= 66 % wheat bran + 8.25 NSC+24.75 BSG + 1% salt
T5= 66 % wheat bran + 33 BSG + 1% salt

Data analysis

Collected data were coded and processed into MS excel and analysis was done undertaken using the GLM procedure of SAS (SAS, 2009). Significance level was tested at $P < 0.05$.

Partial budget analysis

The partial budget analysis and net return were calculated to determine the profitability of the four different supplemental feeds that were fed to the lactating cows under on station management conditions. According to (Ehui *et al*., 1992) Net income (NI) is calculated as the amount of money left when total variable cost (TVC) is subtracted from total returns (TR). In this experiment the variable costs included estimated purchase price of the basal and supplemental feed cost and labor cost for preparation of the supplemental feed and cost for medicaments and treatments. While total return (TR) was estimated average sale price of milk produced during the experimental period per animal per day within treatment (NI= TR- TVC). Change in net income (ΔNI) was computed as the difference between change in total return (ΔTR) which was total return of the given treatment minus total return of the control treatment (T1) and change in total variable cost (ΔTVC) Total variable cost of the treatment minus total variable cost of the control. $\Delta NI = \Delta TR - \Delta TVC$.

Results and Discussions

Feed intake

The result indicates that the total dry matter intake and body weight gain doesn't differ among the treatments. It is in line with the findings of Christa L M., 2010 who replaced brewery spent grain with corn silage in the diet of lactating cows in which the dry matter intake was not different across the treatments.

The current result is contradicting with the findings by Getu K. *et al.* in 2019 who reported the total DM and body weight of the animals decreased as the level of BSG substitution increased. The difference might be due to the blood level of crossbred cows used for the experiment where they use high grade crossbred cows.

The result was inconsistent with the findings of AL-Talib *et al.*, 2014 who reported significant improvement in amount of concentrate feed intake in increasing levels of dried brewery grain in feeding lactating dairy cows. The difference might be attributed by the type of brewery grain used as they use dried one.

Table 2. Mean (±SE) feed intakes of HF x Arsi crossbred cows fed on different levels of brewery spent grain substitute Noug seed cake protein sources

Parameters	Treatments					Sig
	T1	T2	T3	T4	T5	
Feed offered (kg/day)	8±0	8±0	8±0	8±0	8±0	Ns
Feed leftover (kg/day)	.4±.1	.6±.1	.6±.2	.8±.1	.7±.1	Ns
Feed intake (kg/day)	7.6±.1	7.4±.1	7.4±.2	7.2±.1	7.3±.1	Ns

Milk production and Composition

The findings showed that the daily milk output of lactating F1 HF X Arsi cows did not significantly differ across the treatments which is consistent with the findings of Christa L M., 2010 who replaced brewery spent grain with corn silage in the diet of lactating cows. The table shown below shows the average daily milk yield per cow, with an overall mean of 7.5 ± 0.2 liters per cow. The results contradict the findings of Getu K *et al.,* 2019and Endale Y *et al.,* 2024, which showed that milk output increased with an increase in the amount of brewery leftover grain included. The result was inconsistent with the findings of AL-Talib *et al.,* 2014 who reported milk yield were highly significant among the milking Frisian cows feeding different levels of dried brewery grain. The difference might be due to the difference in the form of brewer grain used as we use fresh ensiled brewery spent grain.

Our findings suggested that spent brewery grain can replace the Noug seed cake in the feed of lactating F1 HF X Arsi cows without reducing milk yield. This result is consistent with that of Getu K. *et al.,* 2019 and Endale Y *et al.,* 2024, who discovered that crossbred dairy cows' diets may incorporate brewery spent grain in place of the protein source present in oilseed cake.

The findings showed that the milk composition of lactating animals fed feeds with varying amounts of brewery spent grain did not differ significantly. The result is consistent with findings of Endale Y. *et al.,* 2024 who reported the composition of milk remain unchanged except the fat which exhibited a declining trend. The outcome differed with the research conducted by Getu K. *et al.,* in 2019, who found that the replacement levels of ensiled BSG to cotton seed cake varied in their reports' effects on milk composition. The observed variation in the protein source feed could potentially be attributed to the substitution of brewery spent grain.

In contrast to the current result AL-Talib *et al.,* 201 reported milk composition of the milking Frisian cows feeding different levels of dried brewery grain were highly significant. The difference might be due to the difference in the form of brewer grain used as we use fresh ensiled brewery spent grain.

Table 3. Milk yield and composition of crossbred cows fed on different levels of brewery spent grain substitute Noug seed cake protein sources

Variables	Treatments						
	T1	T2	T3	T4	T5	SEM	P value
Milk yield Kg/day	7.5	7.37	7.67	7.47	7.64	0.44	0.98
Fat %	4.14	4.25	4.07	3.98	4.01	0.20	0.95
Protein %	3.09	3.16	3.17	3.14	3.15	0.05	0.45
Lactose %	4.67	4.74	4.71	4.72	4.74	0.07	0.82
SNF %	8.45	8.68	8.59	8.62	8.63	0.14	0.16
pH	6.45	6.43	6.51	6.46	6.42		0.80
BW (Kg)	292.5	293.3	289.6	294.0	293.8	11.2	0.99

Partial budget analysis

Partial budget analysis indicated that the net benefit is high for animals receiving dietary treatment 5 (100%) replacement of Noug seed cake by ensiled brewery spent grain followed by treatment 3 and 4. The current result is similar with the findings of Endale Y. *et al.* (2024), who reported that the net benefit was high for cows receiving the highest inclusion rate of brewery spent grain. The highest net benefit was obtained from animals fed on dietary treatment 5 which was 272.4 ETB/cow/day.

Table 4. Partial budget analysis of crossbred cows fed on different levels of brewery spent grain substitute Noug seed cake protein sources

Variables	Treatments				
	T1	T2	T3	T4	T5
Milk yield (lit/cow/d)	7.5	7.4	7.7	7.5	7.6
Gross benefit (ETB /cow/d)	450.0	442.2	459.0	448.2	458.4
Cost of BSG (ETB/cow/d)	0.0	3.7	7.5	11.2	14.9
Cost of NSC (ETB/cow/d)	47.5	35.6	23.8	11.9	0.0
Cost of wheat bran (ETB/cow/d)	60.7	60.7	60.7	60.1	60.1
Cost of common salt (ETB/cow/d)	1.0	1.0	1.0	1.0	1.0
Cost of Rhodes grass hay (ETB/cow/d)	60.0	60.0	60.0	60.0	60.0
Labor cost (ETB /cow/d)	50.0	50.0	50.0	50.0	50.0
Total variable cost (ETB /cow/d)	219.4	211.1	202.9	194.1	186.0
Net benefit (ETB /cow/d)	230.6	231.1	256.1	254.1	272.4

Note: WB: 23ETB/Kg, NSC: 36 ETB/kg, BSG: 11.3ETB/kg, Hay: 15ETB/Kg, salt: 25ETB/kg, Milk: 60ETB/liter

Conclusions and Recommendations

Overall, incorporating BSG into dairy cow diets can be beneficial for both milk production and farm economics, but it requires careful management to ensure consistent supply and proper adaptation.
Inclusion of brewery spent grain in diet of lactating crossbred cows has no negative effect on milk yield and composition.
The highest net benefit was obtained from animals fed on dietary treatment 5 which was 272.4 ETB/cow/day.
Ensiled brewery spent grain can substitute biological and economical protein source noug seed cake in the diet of lactating crossbred dairy cows without affecting milk yield and composition.
Based on partial budget analysis, Dietary treatment 5 (wheat bran + Brewery spent grain+ salt) was recommended for further evaluation and intervention at on farm level for dairy producers who kept crossbred cows and have access for brewery spent grain especially for urban and peri urban dairy producers.

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Foxtail Millet *Setaria italica* (L.): Acceptability of Indigenous Food Products Among the Mindanaoans, Philippines

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Abstract

Foxtail millet (*Setaria italica* (L.) P. Beauv.) is one of the indigenous food crops in the Philippines. It is a marginalized cereal crop known for its climate resiliency and nutritional properties. Along with the green revolution and change in crop production preferences, it is left uncirculated thus regarded as a nearly forgotten crop. This study was conducted to assess the acceptability of traditional food products derived from foxtail millet as identified by foxtail millet growers in Northern Mindanao. Four traditional food products were prepared, namely: "dawacaldo", "biko", plain porridge, and "puto". These food products were subjected to sensory evaluation by 60 respondents of different age brackets using a 9-point Hedonic rating scale. Among the evaluators, 72% had no knowledge about the crop. Frequency counts, mean, standard deviation and one-way ANOVA were used to analyze the data gathered. Significant differences between treatment means were determined using the Least Significant Difference (LSD) Test. Results revealed that the four food products derived from foxtail millet were "liked very much" to "liked extremely" by evaluators across age groups. Nevertheless, "*dawacaldo"* was the most preferred among the products served to them. Dawacaldo is an enriched porridge with addition of chicken and herbs that improved its total acceptability. Thus, this food product was highly acceptable by the community. Yet, there is a dire need for reintroduction of foxtail millet in the Philippines and the commercialization of its food products.

Keywords: *Foxtail millet, Sensory evaluation, Hedonic rating scale*

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Evaluation Of The Antioxidant Potentials Of Fruit Peels Extract

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Abstract

This experiment aimed to evaluate the antioxidant potentials of sweet orange, shaddock and lemon peel extracts as an alternative source of synthetic antioxidants like butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT) and tertiary butyl hydroquinone (TBHQ) often used in food industries to enhance the oxidative stability of food products. The peels of ripe sweet orange, shaddock and lemon fruits were oven-dried and extracted using a standard method. The qualitative and quantitative phytochemical contents, radical scavenging activities and 1,1 – diphenyl 2- picrylhydrazyl (DPPH) abilities of sweet orange peel extract (SOPE), shaddock peel extract (SHPE), and lemon peel extract (LMPE) were also evaluated. Phenolic compounds, steroids, flavonoids, coumarins triterpenes and alkaloids were found in SOPE, SHPE and LMPE. While phlobatannin, anthocyanin and amino acid were observed to be absent in SOPE, SHPE and LMPE. SOPE contains more steroids (34.43 mg/100g), flavonoids (161.82 mg/100g), terpenoids (17.09 mg/100g), triterpenes (128.27µg/100g) and alkaloids (32.44 mg/100g) than SHPE and LMPE. SHPE contains more phenolics (26.76 mg/100g) than SOPE and LMPE while LMPE contains more tannins (1.74 mg/100g), coumarins (18.15 µg/100g) than SOPE and SHPE. The study showed that SOPE, SHPE and LMPE contains useful natural antioxidants that can serve as alternative preservative agents and antioxidants to butylated hydroxyanisole (BHA), a synthetic antioxidant.

Keywords: *Antioxidants, Oxidative stability, Extraction, Fruit Peels, Phytochemicals*

Introduction

Varieties of fruits are in abundance in Nigeria, to which after consumption, its peels constitute a nuisance as wastes and potential hazard to the environment. Specifically, peels of the fruits which, when accumulated over time, may, through runoff pollute potable water, stream and rivers or become a hideout for poisonous reptiles and insects (Manthey and Grohmann, 2001). Consequently, a considerable amount of money and time is spent disposing of peels as a waste product. Hence, any processes that will convert these wastes to useful end-products will not only be obtaining a valuable product from a cheap and readily available source but also help in recycling waste.

Phytochemical studies of several fruits showed that phenolic compounds like phenolic acids, flavonoids, glycosides, , and alkaloids, are much more concentrated in the peels than the fruit pulp (Lucia et al.,2008; Ignat et al., 2011). The phytochemicals are extracted from the peels using alcohols by procedures described by some researchers (Calabro et al., 2004; Sultana et al., 2009; Van Acker et al., 2011). The phytochemicals may contain both beneficial (antioxidants) and anti-nutritional compounds. Some compounds like saponins, phenolics, alkaloids, glycosides and tannins are examples of anti-nutritional compounds that inhibit both animal and human growth, also impair intake and utilization of food and feeds (Pihlanto et al., 2017). Despite their anti-nutritional effect, these compounds can also be beneficial in their activities. For example, tannins and phytic acids while being anti-nutrients, may also have beneficial effects on humans in the treatment and prevention of many pathological conditions and cancer (Silva and Bracarense, 2016). Saponins may contain a plasma cholesterol-lowering effect, which is important in reducing the risk of some chronic diseases in humans (Singh et al., 2017). Glycosides and their related hydrolytic products are believed to reducing the risk of chronic diseases like cardiovascular diseases and various forms of cancer and inflammatory disorders (Jaafaru et al., 2018). It has been observed that human bodies under stress conditions produce less enzymatic antioxidants like superoxide dismutase (SOD), glutathione peroxidase (GPx), and catalase (CAT) and non-enzymatic antioxidants like ascorbic acid (vitamin C), tocopherol (vitamin E) (Manjula and Ammani, 2012). An imbalance in the above activities could damage the body cell and other health challenges (Steer et al., 2002).

Fruit peels contain lots of free radical scavenging molecules some of which include alkaloids, vitamins, terpenoids, phenolic acids and tannins as well as other secondary metabolites with a high level of antioxidant activity (Manjula and Ammani, 2012). Most phytochemicals are natural antioxidants and can be used as an alternative to synthetic antioxidants like butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT) and tertiary butyl

hydroquinone (TBHQ) which essentially reduce the damages caused in tissue during physiological processes (Ignat et al., 2011). This research was aimed at determining the qualitative and quantitative phytochemical components in the peels of some of the important fruits in Nigeria, like sweet orange, shaddock and lemon, as indices of producing secondary plant metabolites which have antioxidant values as well as application in food industries.

Materials And Methods

Materials

Ripe sweet oranges (*Citrus sinensis)*, shaddock (Citrus maxima), and lemon (*Citrus limon*) fruits were collected from the Lower Niger River Basin Authority farm, Ilorin, Kwara State. The materials used are; Sieve with diameter 142.56 µm, Soxhlet apparatus, Knives, Rotary evaporator dark bottles, and fridge. Chemicals include; Folin-ciocalteu reagents, ethanol, aluminum chloride was used in this study.

Methods

Preparation of the extracts of sweet orange peel (SOP), shaddock peel (SHP), and lemon peel (LMP)

The experiment was carried out in the School of Agriculture and Agricultural Technology, Animal Production Laboratory, Federal University of Technology, Minna. Agricultural Laboratory of Kwara State University, Malete, Nigeria and Central Research laboratory, Tanke, Ilorin, Nigeria Ripe sweet orange, shaddock, and lemon fruits were washed with water, peeled manually using a stainless-steel knife, and edible parts separated. The peels were oven-dried (using Gallenhamp oven, 300 plus series model) at 40 ^{O}C for 48 hours. The dried samples were ground to a fine powder using a blender (Smart Leaf VTCL, 18,000 rpm capacity, India) and passed through a 24 mesh-size sieve (142.56µm) according to the method described by Van Acker et al. (2011). The organic solvent extraction method was used to extract the phenolic compounds. A total of 50 g of each of the powdered samples were extracted with 400 ml ethanol at room temperature by the soxhlet extraction method for 3 hours. The mixture was decanted to remove the debris. The extraction procedures were repeated twice under the same condition to ensure complete extraction

Finally, the extracts were filtered and evaporated to dryness under reduced pressure at 60 ^{0}C by a rotary evaporator (RE-52A Model, England). The extracts were then kept in the dark bottles and stored in the refrigerator at 4 ^{0}C for 48 hours.

Qualitative analysis of the phytochemicals of the extracts

Test for tannins

Analysis used was the method reported by Ejikeme et al. (2014). About 0.03 g of each extracted samples was weighed into a test tube and boiled for 10 minutes in a water bath containing 30 cm^3 of water. The contents were filtered after boiling using number 42 (125 mm) Whatman filter paper.1 cm^3 of freshly prepared 10% potassium hydroxide (KOH) was added to 1 cm^3 of the extract samples. A dirty white precipitate indicates the presence of tannins.

Test for phlobatannins

About 0.30 g of each extract sample were weighed into a beaker containing 30 cm^3 of distilled water. 10 cm^3 of each sample were measured and boiled with 5 cm^3 of 1% aqueous hydrochloric acid (HCL). A red precipitate indicates the presence of phlobatannins (Ejikeme et al., 2014).

Test for saponin

About 30 cm^3 of distilled water was added to 0.30 g of each extract sample and boiled for 10 minutes in a water bath after which were filtered using Whatman filter paper number 42 (125 mm). A mixture of 5 cm^3 distilled water and 10 cm^3 of the filtrate was agitated vigorously until froth was observed. The formation of emulsion on the addition of 3 drops of olive oil indicates saponin (Ejikeme et al., 2014).

Test for steroid

About 0.30 g of each of the extract samples were weighed into a beaker and diluted with 2 cm^3 acetic anhydride followed by 5 drops of concentrated tetraoxosulphate (VI) acid (H_2SO_4). A red colour change in the sample(s) indicates steroids (Ejikeme et al., 2014).

Test for terpenoids

About 5 ml of aqueous extract of the samples was mixed with 2 ml of $CHCL_3$ in a test tube and 3 ml of concentrated tetraoxosulphate (VI) acid (H_2SO_4) was carefully added to the mixture to form a layer. An interface with a reddish-brown colouration indicates the presence of terpenoids (Ejikeme et al., 2014).

Test for flavonoids
About 1 cm^3 of 10% sodium hydroxide (NaOH) was added to 3 cm^3 of each aqueous extract sample. An intense yellow colour appeared which became colourless with the addition of a few drops of dilute acid which indicates the presence of flavonoids (Muhammad and Amzad, 2014).

Test for alkaloids
About 1 cm^3 of 1% hydrochloric acid (HCl) was added to 3 cm^3 of each extract sample in a test tube. The mixtures were then heated for 20 min, cooled and filtered using Whatman filter paper number 42 (125 mm). About 2 drops of Wagner's reagent were added to 1 cm^3 of the filtrates. A reddish-brown precipitate indicates the presence of alkaloids (Rufai et al.2016).

Test for glycoside
About 10 cm^3 of 50 % tetraoxosulphate (VI) (H_2SO_4) was added to 1 cm^3 of the extract samples. The mixtures were then heated in boiling water for 15 min. 10 cm^3 of Fehling's solution was added and the mixture boiled for another 10 min. A brick red precipitate indicates the presence of glycosides (Rufai et al. 2016).

Test for phenolics
About 2 drops of 5 % iron chloride ($FeCl_3$) was added to 1 cm^3 in each of the test tube containing the extract samples. A greenish precipitate indicates the presence of phenols (Kun-ze et al. 2018).

Test for coumarins
About 0.5 g of the peel extracts of sweet orange, shaddock, and lemon fruits was covered with filter paper moistened with 1 M of sodium hydroxide (NaOH) in a small test tube. The test tube was immersed in boiling water bath. The filter paper was removed and examined in ultraviolet light for yellow fluorescence which indicates the presence of coumarin (Kalpana et al. 2014).

Test for triterpenes
About 5 drops of acetic anhydride were added to 1 cm^3 of the extract's samples. A drop of concentrated sulphuric acid (H_2SO_4) was later added, and the mixture was steamed for 1 hr. and subsequently neutralised with sodium hydroxide (NaOH), then with chloroform added to the solution. A blue-green colour indicates the presence of triterpenes (Katrizky, 1995).

Quantitative analysis of the phytochemicals of the extracts
Total tannin content determination
About 0.20 g of the extract samples were measured into a 50 ml beaker containing 20 ml of 50 % methanol, which was later covered with paraffin and boiled in a water bath at 77 – 80^o C for an hour. The contents were thoroughly shaken and filtered using a double-layered Whatman number 41 filter paper into a 100 ml volumetric flask. 20 ml of water, 2.5 ml of Folin-Denis reagent and 10 ml of 17 % sodium carbonate (Na_2CO_3) were added into the content in the volumetric flask and mixed properly. More quantity of water was added into the mixture in the volumetric flask up to the mark and allowed to stand for 20 min., after which a bluish-green colour was observed. 0 – 10 ppm was produced following the above procedure as a 1 ml blank sample. The absorbance readings of the tannic acid standard solution and the samples were read after colour development on a Spectronic 21D spectrophotometer at a wavelength of 760 (Amadi et al. 2004). Total tannin was calculated using the formula:

$$Total\ tannin = absorbance\ x\ average\ gradient\ x \frac{dilution\ factor}{wt\ of\ sample}$$

Total saponin content determination
About 1 g of the extract samples were weighed into a 250 ml beaker, and 100 ml of isobutyl alcohol was added. The contents were shaken on a UDY shaker for 5 hr. to ensure uniform mixing. The contents were then filtered through a Whatman number 1 filter paper into a 100 ml beaker containing 20 ml of 40 % saturated solution of magnesium carbonate ($MgCO_3$). The obtained mixtures were again filtered to get a clear colourless solution. About 1 ml of the filtrates were pipette into a 50 ml volumetric flask containing 2 ml of 5 % iron chloride ($FeCl_3$) solution and distilled water was added to make up to the mark level of the flask. The contents in the flask were allowed to stand for 30 min for a blood-red colour to develop. 0 – 10 ppm saponin standard was prepared and treated with 2 ml of 5 % iron chloride ($FeCl_3$) following the same procedure described earlier. The absorbance of the samples and standard saponin solution was read after colour development using a Jenway V6300 spectrophotometer at a wavelength of 380nm (Ejikeme et al. 2014). The quantity of saponin was calculated as follows:

$$Total\ saponin = absorbance\ x\ average\ gradient\ x \frac{dilution\ factor}{weight\ of\ sample\ x\ 10{,}000}$$

Total steroid content determination

About 0.05 g of extract samples were weighed into a 100 ml beaker. Chloroform – methanol (2 ml) with a ratio of 2:1 was added, and the content was shaken for 30 min to dissolve the extract samples. 1 ml of the content was pipette into a 30 ml test tube containing 5 ml of alcoholic potassium hydroxide (KOH) and shaken thoroughly until a homogenous mixture was obtained. The mixture was then placed in a water bath at 37° C - 40° C for 1 hr. 30 min. The contents were cooled to room temperature and 10 ml of petroleum ether was added with 5 ml of distilled water. The content was later evaporated to dryness on the water bath. 6 ml of Liebermann Buchard reagent was added to the residue in a dry bottle, and absorbance reading was taken on Spectronic 21 D digital spectrophotometer at a wavelength of 620nm. A standard solution of 0 – 4 mg/ml was prepared and followed the same procedure earlier described by Chukwuma and Chigozie (2016). Total steroid content was calculated as follow:

$$Total\ steroid = absorbance\ of\ sample\ x\ average\ gradient\ x \frac{dilution\ factor}{weight\ of\ sample\ x\ 10.000}$$

Total terpenoid content determination

Liquid chromatography-electrospray ionization – mass spectrometry method described by Feng et al. (2013) was used. 0.5 g of the extracts were mixed with 0.03 % formic acid aqueous solution in 45 min. The chromatographic separations were achieved on an Agilent Poroshell SB-C_{18} column (150x 4.6mm, 3.5 µm) with gradient elution using acetonitrile. Detection was performed in the positive ionization mode by monitoring the precursor-extract combination.

Total flavonoid content determination

Total flavonoids of the peel extract samples were determined using the aluminum chloride colorimetric assay method (Calabro et al.2004; Ebrahimzadeh et al. 2008). About 1 ml of the extract samples and 500 µg/ml standard solution of quercetin were added to a 10 ml volumetric flask containing 4 ml of distilled water. After that, 0.3 ml of 5 % sodium nitrite ($NANO_2$) was added. 5 min after, 0.3 ml of 10 % aluminum chloride ($AlCl_3$) was added. 6 min later, 2 ml of 1 M sodium hydroxide (NaOH) was added and distilled water was added to make up the total volume of the content to be 10 ml. The content was mixed thoroughly and the absorbance reading of the colorimeter was measured against the prepared reagent blank at 510 nm. The total flavonoid content of the samples was measured as mg of quercetin equivalent per 100 g of fresh content.

Total alkaloid content determination

The quantitative determination of alkaloids was done by the procedure described by Hikino et al. (1984). About 2 g of the extract samples were weighed into a 100 ml beaker and 20 ml of 80 % alcohol was added to give a smooth paste. The resulting content was poured into a 250 ml round bottom flask and more alcohol was added together with 1 g of magnesium oxide. The mixture was then digested in a boiling water bath for 1 hr. 30 min under a reflux air condenser and occasionally shaken the content. The mixture was filtered while still hot through a Buchner funnel. The residue was transferred into the flask and re-digested for another 30 min with 50 ml alcohol and the alcohol evaporated later. Three drops of 10 % hydrochloric acid (HCL) were added. The entire content was later poured into a 250 ml volumetric flask. About 5 ml of zinc acetate and 5 ml of potassium ferricyanide solution were mixed thoroughly to give a homogenous solution. The content in the flask was allowed to stand for a few minutes, filtered through a dry filter paper and 10 ml of the filtrate was poured into a separating funnel and the alkaloids in the content extracted vigorously by shaken with portions of chloroform five times. The residue collected was dissolved into 10 ml of hot distilled water and poured into a Kjedahl tube with a solution of 0.2 g of selenium for digestion to form a colourless solution. The clear colourless solution was used to determine the nitrogen using the Kjeldahl distillation apparatus. The distillate was later back titrated using 0.01 mole hydrochloric acid (HCl), and the titre value obtained was used to calculate the percentage nitrogen as follow:

$$\%\ N = titre\ value\ x\ atomic\ mass\ of\ nitrogen\ x\ normality\ of\ HCl\ x \frac{100}{weight\ of\ sample}$$

% Alkaloid = % Nitrogen × 3.26 where 3.26 is a constant

Total glycoside content determination

About 10 ml of extract samples were pipette into a 250 ml conical flask. 50 ml of chloroform was added and mixed thoroughly on a Vortex mixer for an hour. The sample mixtures were filtered into a conical flask, and 10 ml of pyridine with 2 ml of 2 % sodium nitroprusside were added and shaken for 10 min. Three ml of 20 % sodium hydroxide (NaOH) was subsequently added to develop a brownish yellow colour. Glycoside standards ranging from 0 – 5 mg/ml were prepared from 100 mg/ml stock glycoside following the procedure earlier discussed. The absorbance of samples, as well as standard, were read on a spectronic 21 D digital spectrophotometer (Thermo

Milton Roy, number 49983-1, France) at a wavelength of 510 nm (Amadi et al., 2004). The total glycoside of each of the extract samples was calculated as follow:

$$Total\ glycoside = absorbance\ of\ sample\ x\ average\ gradient\ x \frac{dilution\ factor}{wt.of\ sample\ x\ 10{,}000}$$

Total phenols content determination

The total phenolic content of the samples was determined using the method described by Talari et al. (2012). The aliquots of the extract samples were poured into a test tube with distilled water added to it to reach a volume of 1 ml. A quantity of 0.5 ml Folin-Ciocalteu reagent (1:1 with water) together with 2.5 ml 20 % of a sodium carbonate solution was sequentially added into the test tube. After the vortex of the reaction mixture, the test tubes were placed in the dark cupboard for 40 min. The absorbance of the solutions was taken at a wavelength of 725 nm using a spectrophotometer (Thermo Milton Roy, number 49983-1, France) against the blank reagent. Using Gallic acid monohydrate, a standard curve was prepared. The linearity obtained was in the range of 1 – 10 µg/ml. Using the standard curve, the total phenolic content was calculated and expressed as Gallic acid equivalent in mg/g of the extracts.

Total coumarin content determination

According to the procedure described by Isabella et al. (2016). 0.5 ml of 5M of sodium hydroxide (NaOH) was added to 1 ml of the extracts and heat at 80 °C for 5 min. 0.75 ml of 5M sulphuric acid (H_2SO_4) was added into the cooled content and mixed thoroughly with 0.25 g of anhydrous $NAHCO_3$, which was later transferred to the extractor. The content was later extracted for 3 hrs. with petroleum ether. 20 ml of water was added to the petroleum ether extract and carefully evaporated the petroleum ether in a water bath at 50 – 55 °C. The aqueous solution was then transferred into a volumetric flask to the 50 ml mark and continuously mixing content. About 25 ml of the solution was pipette into a flask and add few drops of 1 % sodium carbonate (Na_2CO_3) solution and heat in a water bath at 85 °C for 15 min and cool. Add 5 ml of diazonium solution and was left to stand for 2 hrs. The absorbance was read at 540 nm against the blank reagent. The total coumarin was calculated from the standard curve derived.

Total triterpenes content determination

According to the procedure described by Pérez-Camino and Cert (1999). A quantity of 0.5 g of extract samples were weighed into a 50 ml conical flask, and 20 ml of 2:1 chloroform-methanol mixture was added, thoroughly shaken and allowed to stand for 15 min. The supernatant produced was discarded and the precipitate rewashed with 20 ml of 2:1 chloroform-methanol mixture and centrifuged. The resultant precipitate was dissolved in 40 ml of 10% sodium dodecyl sulphate (SDS) solution. 1 ml of 0.01 M ferric chloride ($FeCl_2$) solution was added to the content for intervals of 30 sec. The content was shaken thoroughly and allowed to stand for 30 min. Standard triterpenes of 0 – 5 mg/ml were prepared from 100 mg/l stock solution obtained from Sigma – Aldrich chemicals, Germany. The absorbance readings of samples and that of the standard concentrations of triterpenes were read on a digital spectrophotometer (Thermo Milton Roy, number 49983-1, France) at a wavelength of 510 nm. The total amount of triterpenes was determined using the formula:

$$Total\ tritepene = absorbance\ of\ sample\ x\ average\ gradient\ x\ \frac{dilution\ factor}{wt.of\ sample\ x\ 10{,}000}$$

1,1 – diphenyl 2- picrylhydrazyl (DPPH) determination

The DPPH ability of each of the peel extracts were monitored according to the method described by Barros et al. (2007) 1 ml of each of the extract samples was added to 4 ml of 0.1 mmol L-1 methanolic solutions of DPPH. A blank solution was obtained by mixing 4 ml of 0.1 mmol L-1 methanolic solutions of DPPH and 200 µl of deionised distilled water. After 30 min of incubation in the darkroom at room temperature, the absorbance was read at a wavelength of 517 nm using a spectrophotometer (Thermo Milton Roy, number 49983-1, France) against a prepared blank solution. Inhibition of free radicals by DPPH in percent was calculated as follows:

% DPPH inhibition = 100 – ({absorbance of sample – absorbance of blank}/ control absorbance) × 100

Statistical analysis

The data of quantitative phytochemical compounds, DPPH, and radical scavenging activities were analyzed in a completely randomized design using the MIXED procedure of SAS (SAS, 2014). Means were separated with the Tukey HSD test at a $p < 0.05$ level of significance.

Results And Discussions

Phenolic compounds in peel extracts of sweet orange, shaddock, and lemon fruits

The results of the qualitative phytochemical screening of sweet orange, shaddock and lemon peel extracts are presented in Table 1. The results showed the presence of various secondary metabolites (saponin, tannins, phenolics, steroids, flavonoids, coumarins, terpenoids, glycosides, triterpenes and alkaloids). Sweet orange peel extract (SOPE) contained saponin, phenolics, steroids, flavonoids, coumarins, terpenoids, glycosides, triterpenes and alkaloids. Shaddock peel extracts (SHPE) contained saponin, tannins, phenolics, steroids, flavonoids, coumarins, terpenoids, triterpenes and alkaloids. While Lemon peel extracts (LMPE) contain tannins, phenolics, steroids, flavonoids, coumarins, glycosides, triterpenes and alkaloids. Phlobatannin is absent in all the peel extracts. From the study, the phenolics, steroids, flavonoids, coumarins, triterpenes and alkaloids that are present in sweet orange, shaddock and lemon peel extracts, are due to the fact that practically all fruit plant tissues can manufacture phenolic chemicals in their pulp or peels (Shahidi and Naczk, 2004; Ishola et al. 2017). The findings of this study are consistent with those of Hafiz *et al*. (2020), who found polyphenol content and antioxidant potential in twenty different fruit peel samples using an ethanolic extraction method, as well as detailed characterisation and quantification using LC-MS and HPLC. In a study to investigate the qualitative presence of natural antioxidants in grape seed peels, faba bean peels, buck-wheat peels, and oil hemp seed peels, Medina (2011) discovered the presence of certain natural antioxidants in bulk wheat, grape seed peels, faba bean peels, and oil hemp seed peels.

Table1. Qualitative Phytochemical Screening of SOPE, SHPE and LMPE

Compounds	Treatments		
	SOPE	SHPE	LMPE
Saponin	+	+	-
Tannins	-	+	+
Phenolics	+	+	+
Phlobatanin	-	-	-
Steroids	+	+	+
Flavonoids	+	+	+
Coumarins	+	+	+
Terpenoids	+	+	-
Glycosides	+	-	+
Triterpenes	+	+	+
Alkaloids	+	+	+

+ = There is the presence of the phytochemicals; = Absence of the phytochemicals

The quantitative results of phytochemical compounds in SOPE, SHPE and LMPE are presented in Table 2. There were significant differences ($p<0.05$) in all the phytochemical compounds measured in sweet orange, shaddock and lemon peel extracts. Sweet orange peel extract contains significantly higher steroids (34.43 mg/100g DW), flavonoids (161.82 mg/100g DW), terpenoids (17.09 mg/100g DW), glycosides (2.00 mg/100g DW), triterpenes (0.13 mg/100g DW) and alkaloids (32.44 mg/100g DW) than SHPE and LMPE. Shaddock peel extract (SHPE) had more saponin content (0.42 mg/100g DW) and phenolics (26.76 mg/100g DW) than SOPE and LMPE. Whereas, lemon peel extract (LMPE) had more tannins contents (1.74 mg/100g DW) and coumarins (0.05 mg/100g DW) than SOPE and SHPE (Table 2). The total phenolic compounds in saponins and phenolics that was found to be higher in shaddock peel extracts (SHPE) (0.42 and 26.76 mg/100 g DW) as compared to sweet orange peel extracts (SOPE) (0.19 and 2.68 mg/100 g DW) and LMPE (0.00 and 1.79 mg/100 g DW), could be owing to the abundant betacyanin pigments found in shaddock plants, which have been linked to the formation of phenolic compounds in plant tissue by raising the phenolic content (Shahidi *et al*., 2019). This study was consistent with the findings of Nurliyana *et al*. (2010), who discovered that dragon fruit peel contains more phenolic chemicals than grape and mango fruit peel. Tannins are a type of phenolic substance that can be divided into two categories: hydrolysable and condensed tannins. The increased tannin content of lemon peel extract LMPE (1.74 mg/100 g DW) compared to SHPE (1.63 mg/100 g DW) and SOPE could be attributed to the long ripening process in lemon fruit, which can slow the rate at which tannin is hydrolysed. Overall, the findings are consistent with those of (Hafiz *et al*.,2020), who discovered that avocado peel had a greater total tannin concentration (9.01 0.20 mg CE/g) than mango, sweet orange, and lemon peel.

The low value of SOPE (0.00 mg/100 g DW) may be related to the hydrolysable kind of tannin it contains, which frequently drops during the ripening process (Masibo and He, 2008). The highest amount of flavonoid was found in the SOPE (161.82 mg/100 mg DW), followed by LMPE (160 mg/100 mg DW) and SHPE (148.13 mg/100 mg DW), corroborate with those of Marina and Noriham (2014), who found that mango peel contains more flavonoids than other tropical fruit peels including guava and pineapple peels. Flavonoids are found in higher concentrations

in tropical fruits that ripen quickly. However, the flavonoid content variation observed in this study varies from that reported by Ayala – Zavala *et al*. (2011), who discovered increased flavonoid content in lemon and other tropical fruits. This could be due to changes in growing regions, environmental circumstances, variety differences, and extraction methods. Fruits grown in different climates have variable flavonoid content in their peels, with the peels being the exterior part of the fruit body exposed to more sunlight than the pulp, resulting in the synthesis of flavonoids that are plentiful and diversified. The flavonoid profile of the same fruits cultivated in different regions under varied climatic circumstances, soil qualities, and cultivation practices has a variable flavonoid profile (Loh *et al*., 2017). Furthermore, the extraction efficiency of flavonoids varies depending on extraction parameters such as solvent type, solvent concentration, extraction duration and temperature, and solvent-to-solid ratio (Ruiz-Montanez *et al*., 2014). Glycosides, triterpenes and alkaloids that were higher in SOPE (2.00, 0.13 and 32.44 mg/100 mg DW) compared with LMPE (0.88, 0.12 and 6.55 mg/100 mg DW) and SHPE (0.00, 0.11 and 4.03 mg/ 100 mg DW), suggest that secondary metabolites such as glycosides, triterpenes, and alkaloids were simpler to extract from sweet orange peel than lemon or shaddock peel using the methanol extraction method. The findings of this study correspond with those of Amin *et al*. (2017), who found that utilising the methanol extraction method, the contents of metabolites such as alkaloids were simpler to extract in orange peel than in lemon peel.

Table 2. Quantitative Phytochemical Screening of SOPE, SHPE, and LMPE

Compounds	SOPE	Treatments			
		SHPE	LMPE	SEM	P value
Saponin (mg/100g DW)	0.19^{b}	0.42^{a}	0.00^{c}	0.01	<0.0001
Tannins (mg/100g DW)	0.00^{c}	1.63^{b}	1.74^{a}	0.02	<0.0001
Phenolics (mg/100g DW)	2.68^{b}	26.76^{a}	1.79^{c}	4.23	<0.0001
Steroids (mg/100g DW)	34.43^{a}	25.60^{c}	32.85^{b}	3.20	<0.0001
Flavonoids (mg/100g DW)	161.82^{a}	148.13^{c}	160.34^{b}	0.01	<0.0001
Coumarins (mg/100g DW)	0.03 ^{b}	0.01^{c}	0.05^{a}	0.01	<0.0001
Terpenoids (mg/100g DW)	17.09^{a}	14.13^{b}	0.00^{c}	2.10	<0.0001
Glycosides (mg/100g DW)	2.00^{a}	0.00^{c}	0.88^{b}	2.03	<0.0001
Triterpenes (mg/100g DW)	0.13^{a}	0.11^{c}	0.12^{b}	0.01	<0.0001
Alkaloids (mg/100g DW)	32.44^{a}	4.03^{c}	6.55^{b}	6.54	<0.0001

$^{a, b, c}$ means having different superscripts along the same row are significantly different ($p < 0.05$)

The results of the interactive effect among sweet orange, shaddock and lemon peel extracts and the concentration on the per cent inhibition are presented in Table 3. there were interactions ($p<0.05$) among the sweet orange, shaddock and lemon peel extracts and their concentrations measured at different per cent inhibition levels. At inhibition level measured at 20, 40 and 60 %, the concentration in mg/ml of shaddock peel extracts was significantly higher ($p<0.05$) than those of sweet orange and lemon peel extracts. However, at inhibition level measured at 80 and 100 per cent, the concentration in mg/ml of sweet orange peel extracts was significantly higher ($p<0.05$) than those of shaddock and lemon peel extracts. But at 100 per cent, the concentration of shaddock and lemon peel extracts were similar. Regardless of the extracts, the concentrations in mg/ml DPPH measured at inhibition level of 100 % was significantly higher ($p<0.05$) compared to concentrations of extracts measured at inhibition levels of 20, 40, 60 and 80 %.

Table 3. 1, G1 – diphenyl 2- picrylhydrazyl (DPPH) and Radical Scavenging Activities of SOPE, SHPE, and LMPE

Extracts	% DPPH Inhibition
SOPE	66.70^{c}
SHPE	83.68^{a}
LMPE	80.48^{b}
SEM	0.02
P- Value	<0.0001
% DPPH Inhibition	Concentration (mg/ml)
20	73.71^{d}
40	57.50^{e}
60	81.07^{c}
80	83.75^{b}
100	88.77^{a}
SEM	0.03
p-Value	<0.0001

$^{a, b, c}$ means having different superscripts along the same row are significantly different ($p < 0.05$)

The result in Table 3 indicated that sweet orange peel extracts had the lowest concentration of 12.76 mg/ml measured at DPPH inhibition level of 40 per cent. When compared to other extracts, the SOPE had a higher DPPH per cent inhibition concentration of 89.27 mg/ml at 100 % inhibition level. This contradicts the findings of Ajila *et al*. (2007), who found that grapefruit peels had a better ability to scavenge DPPH radicals than sweet orange and mango peels (9.17 ± 0.19, 8.67 ± 0.49 and 8.67 ± 0.44 mg AAE/g, respectively). This could be due to the freeze-drying procedure used on the fruit peels. Free radicals are scavenged and neutralized by the freeze-drying process, which produces redox-active metabolites (Castro- Vazquez *et al*., 2016). In other words, SOPE will be more effective at chelating the hydroxyl free radicals in glutathione peroxidase, preventing aging in people and animals and reducing oxidative damage in meat products. This study adds to Sara *et al*. (2008) findings, which indicated that there was a link between glutathione peroxidase, antioxidant enzymes, disease, and aging in humans.

Conclusion

the data and empirical evidence obtained from this study showed that peel extracts of sweet orange, shaddock and lemon fruits contains useful natural antioxidants that can serve as alternative preservative agents and antioxidants to butylated hydroxyanisole (BHA), a synthetic antioxidant.

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In vitro and ruminal characteristics of the three selected Nigerian herbs: Phyllantus amarus, Ocimum gratissimum and Lactuca taraxacifolia as feed additives in ruminant production

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Abstract

The study was conducted to evaluate the effects of herbal feed additives on the in vitro and ruminal fermentation by West African dwarf goats. A total of 20 goats were subjected to five dietary treatments for a 12- week feeding study in a completely randomized design: Feed only (control) (T1), Feed + *Ocimun gratissimum* leaf meal (T2), Feed + *Phyllantus amarus* leaf meal (T3), Feed + *Lactuca taraxacifolia* leaf meal (T4), Feed + P. amarus + O. gratissimum + L. taraxacifolia leaf meal (T5). Phytochemical Screening of the three herbs were carried out. Herbs were added at 3g/kg feed and were given at 5% body weight of the animal. The feed samples were subjected to 24 hours incubation. Gas volume were measured at the interval of 3hrs. At the end of incubation, methane volume was estimated. The gas volume produced was used to calculate metabolizable energy (ME), organic matter digestibility (OMD) and short chain fatty acid (SCFA) concentrations. At the end of the feeding trial, rumen liquor was collected to determine ruminal characteristics and the microbial population as may be affected by the medical plants. The results showed that the leaves of the herbs were rich in saponin, tannin and alkaloid. The three medicinal plants were relatively high in crude protein (CP) and moderate in carbohydrate (CHO) content. Treatment containing the mixture of *O. gratissimum, P. amarus and L. taxifolia* (T5) contained more CP than the rest of the treatments while T2 had the highest CF. There was apparent increase in the value of potential gas production as the incubation period increases in *in-vitro* study. T1 and T4 produced more gas than the rest of the treatments. Methane production was lower in T3 and T5 compared to other treatments. T1 and T4 equally had the highest ME, OMD and SCFA concentrations. However, T3 and T5 improved the ruminal characteristics and microbial population in the rumen as the population was significantly modified. It is therefore concluded that T3 (*Phallantus amarus*) and the combination of the three herbs (T5) be used as feed additives for mitigating methane emission and improve rumen ecology of the animals for enhanced ruminant productivity.

Introduction

Adopting feeding strategies to mitigate the amount of energy lost as methane and reduce ammonia concentration in the rumen can enhance feed conversion efficiency, improve animal productivity and reduce global warming (Gebrehiwot, 2014). Researchers have shown that manipulation of rumen microbial fermentation to decrease methane and ammonia production from ruminant livestock using extracts/meal of herbs and spices has proven to be a potentially useful strategy in improving production efficiency in ruminants (Benchaar *et al.*, 2008; Benchaar and Greathead, 2011). Methane expelled by ruminants is one of the most important sources of global warming, having a great impact on the environment. Greenhouse gas emission, especially methane from ruminants, has been recognized as an important issue worldwide as it is a driver for global warming and climate change (Kim *et al*., 2012). It has been reported that livestock production and its by-products are responsible for at least 51 percent of global warming gases (Goodland and Anhang, 2009). Gas emissions from the livestock sector are estimated at between 4.1 and 7.1 billion tonnes of carbon dioxide equivalents per year, equating to 15-24% of total global anthropogenic greenhouse gas emissions (Wanapat *et al.*, 2013).

Phytogenics, are natural bioactive compounds that are derived from plants and incorporated into animal feed to enhance productivity (Gadde *et al* 2017) and reduction in methane emission to the environment. The incorporation of synthetic antibiotics in the ration of livestock has raised public concerns because of the development of drug-resistant bacteria. However, the use of some herbs and spices has proved to influence the rumen environment (Szumacher-Strabel and Cieślak, 2010; Cieslak *et al.*, 2013). Rezaei and Pour (2012) reported that the addition of thyme methanolic extracts had a reducing effect on the degradability of soybean meal using an in vitro gas production technique. Chaudhry and Khan (2012) in an in vitro rumen fermentation study with five curry spices which include coriander, turmeric, cumin, clove and cinnamon revealed that the spices acted as natural antibiotics, destroying methane-producing bacteria in the animal's gut which led to a reduction in methane production.

Dong *et al.* (2010) reported a reduction in methane production, increased propionate production and decreased protozoa numbers when luzerne extract, *Artemisiae annuae* extract and mixed herbal medicine were included in goat diets. In another study conducted to assess the effect of ginger (*Zingiber officinale*) on the in vitro rumen ecosystem of sheep, Mohammad and Moeini (2015) reported that ginger supplementation improved ruminal fermentation due to a reduction in ammonia, reduction in methane loss, reduction in acetate to propionate ratio and beneficial changes in protozoa population. In addition, Tag El-Din *et al.* (2012) also concluded that the addition of garlic juice and ginger improved rumen fermentation, increased gas production and reduced methane production. Busquet *et al.* (2005) also reported that garlic oil altered rumen fermentation by reducing the acetate to propionate ratio like what is obtainable using monensin in a continuous culture. Kim *et al.* (2012) also reported that plant extracts were shown to have properties to reduce methane production, reduce acetate to propionate ratio, decrease methanogen population and increase fibrolytic bacteria population.

Meanwhile, Mariam *et al.* (2014) investigated the potential impacts of different levels of essential oils blend (eucalyptus, cinnamon, peppermint, thyme and lemon) on rumen fermentation parameters and nutrient utilization in barki sheep and reported no significant effects on *in vitro* gas production, methane production, short chain fatty acids (SCFA), NH_3-N concentration and protozoa count. Notwithstanding, Arhab *et al.* (2013) observed a significant reduction in methane production, rumen fermentation traits and decreased ammonia N concentration when essential oils extracted from *Juniperus phoenicea*, *Satureja calamintha* and *Mentha pulegium* were used in vetch oat hay *in vitro*. To mitigate climate change, there is a need to reduce greenhouse gas (GHG) emissions from all the sectors. Reisinger *et al*. (2021) observed that reduction in global warming to below 2º C cannot be realistic without reducing emissions from the agricultural sector

Studies reported that dietary supplementation with 10 g/DM of plantain herb and/or 10 g/DM of *Allium sativum* (garlic leaf) resulted in enhanced crude protein intake, dry matter intake, feed conversion ratio and body weight gain compared with the control diet (Redoy *et al*., 2020).

Similarly, dietary *Andrographis paniculata* leaves and stems increase feed intake and growth performance in goats (Yusuf, 2015). It has also been reported that the dietary supplement with *Nigella sativa* seeds or *Rosmarinus officinalis* leaves at 1 % concentration enhanced nutrient digestibility in lambs (Odhaib *et al.*, 2018). Moreover, the addition of *N. sativa* leaf meal up to 66.7 % as a replacement for cottonseed meal in the diets of sheep resulted in improved feed utilization and growth performance of growing Farafra sheep (Abdullah and Farghaly, 2019).

Materials and Methods

Experimental Site

The experiment was conducted at the Small Ruminant Unit at Teaching and Research Farm, Kwara State University, Malete, Kwara State. The location is situated on Latitude 8.71^0N and Longitude 4.44^0E (Ogunbosoye *et al.*, 2015) in the southern Guinea Savannah agro-ecological zone of Nigeria.

Experimental Animals

The experimental animals comprised twenty (20) growing WAD goats, sourced within the Ilorin metropolis. They were neck tagged for identification and quarantined upon arrival at the Small Ruminant Unit of the Teaching and Research Farm. The animals were vaccinated against Pestes des Petit Ruminants (PPR) using the PPR vaccine at the rate of 1mL per animal to confer immunity, administered with Albendazole (dewormer at 12.5 mg/kg body weight), dusted with ectoraid against ectoparasites and treated with oxytetracycline HCl (a broad spectrum antibiotic) before the commencement of the experiment. The animals were housed in their pen with *ad libitum* access to clean water.

Procurement and Preparation of Herbs

Phyllantus amarus, *Ocimum gratissimum* and *Lactuca taraxacifolia* were harvested within the school farm in large quantities. They were air dried for 3 -5 days (by laying them over metal mesh rack dryers placed above the floor) at room temperature, then milled into fine powder, sieved through a 1mm gauge and preserved in tightly closed plastic jars until use.

Experimental Design and Diet Formulation

The animals were randomly allotted to five treatments in a completely randomized design (CRD) with four (4) goats in each of the treatments. The five experimental treatments were:

Treatment 1: Feed only (control).
Treatment 2: Feed + *Ocimun gratissimum*
Treatment 3: Feed *Phyllantus amarus*
Treatment 4: Feed + *Lactuca taraxacifolia*
Treatment 5: Feed + *Phyllantus amarus* + *Ocimun gratissimum* + *Lactuca taraxacifolia*

Herbs Administration

The herbs were administered to the goats at 3g/ kg feed as described by Abdelhamid *et al.* (2011). The procedures were repeated every week. The weighted content was served at 8.00 hr. and 16.00 hr. daily throughout the experimental period.

Chemical Composition

The moisture content of the diets was determined by drying in a forced-air oven at 60^0C until constant weight was achieved. After drying, samples were ground to pass a 2 mm sieve and then subjected to proximate analysis according to AOAC, (2005). The carbohydrate content was calculated from the differences in the sum of protein, fat, moisture, and ash content subtracted from 100. Neutral detergent soluble (NDS), Neutral detergent fibre (NDF), Acid detergent fibre (ADF), Acid detergent lignin, Hemicelluloses and cellulose were analyzed according to Van Soest *et al.* (1994) procedure.

In vitro Fermentation

Rumen fluid was obtained from five West African dwarf (WAD) goats through the suction tube before the morning feed and sieved with four layered cheesecloth in continuous flushing with CO_2. To 200 mg sample in the syringe was added 30 ml inoculum that contained rumen liquor and buffer (9.8g $NaHCO_3$ + 2.77g Na_2HPO_4 + 0.57g KCl + 0.47g NaCl + 0.12g $MgSO_4$. $7H_20$ + 0.16g $CaCI_2$. $2H_2O$ in a ratio 1:4 v/v respectively. Incubation was carried out in 120 ml calibrated syringes in five replicates with blank syringes (no substrates) at 39 ± 1º C for 24 hrs. The gas production was measured at 3, 6, 9, 12, 15, 18, 21 and 24h (Menke and Steingass, 1988). The average volume of gas produced from the blanks was deducted from the volume of gas produced per sample.
Metabolizable energy (ME, MJ/Kg DM), organic matter digestibility (OMD %) and short-chain fatty acids (SCFA µmol) were estimated at 24h incubation
ME = 2.20 + 0.136 GV + 0.057 CP + 0.0029CF (Menke and Steingas, 1988).
OMD = 14.88 + 0.88GV + 0.45CP +0.651XA (Menke and Steingas, 1988).
SCFA = 0.0239GV – 0.0601 (Getachew *et al.*, 1999).
Where GV, CP, CF and XA are net gas production (ml/200mg, DM) at 24 h incubation time, crude protein, crude fibre and ash contents of incubated samples respectively.

Methane Production

At the end of 24 hours of incubation, 4 ml of NaOH (10 M) was introduced, following a procedure of Fievez *et al.* (2005). The content was inserted into the silicon tube, which was fastened to the syringe. The clip was then opened while the NaOH was gradually released. The content was agitated while the plunger began to shift position to occupy the vacuum created by the absorption of CO_2. The volume of methane was read on the calibration.

Determination of Rumen Liquor Parameters

pH and NH_3-N Analysis

At the end of the growth study, the goats fasted overnight but water was served *ad libitum*.100ml rumen fluids were collected from the West African Dwarf (WAD) goats according to the treatments using a stomach tube, sieved with a four-layered muslin cloth into a beaker. The pH of the rumen fluid was measured immediately using a pH meter. The collected rumen liquor samples were then strained, frozen and later thawed at room temperature and then shaken. The contents were transferred into glass tubes and centrifuged at 4000 rpm for 10 minutes. The supernatant was analyzed for ruminal ammonia-nitrogen concentration (NH_3-N) by the method of steam distillation with MgO using a Kjeltec distillate unit as described by AOAC (2012). The NH_3-N concentrations were calculated according to the following equation:
NH_3-N (mg/100ml) = [ml. of HCl titrate ×normality of HCl × 0.014 / volume of rumen liquor (1ml)] ×100 (AOAC, 2012)

Total Volatile Fatty Acids Analysis

Total volatile fatty acids (TVFAs) in the rumen liquor were estimated according to the steam distillation method (Samuel *et al.*, 1997). The TVFAs were calculated according to the following equation:
TVFA (mmol/L) = (ml. NaOH titrate ×normality of NaOH/volume of rumen liquor (1ml) ×1000) (Samuel *et al.*, 1997). The molar proportions of individual volatile fatty acids (VFA) were determined by chromatography technique using high-performance liquid chromatography according to the method described by (Filípek and Dvořák, 2009). The rumen fluids were sent to the laboratory to measure the individual volatile fatty acids; acetic acid, propionic acid and butyric acid.

Microbial Count Analysis

Rumen fluid was also used for total direct counts of bacterial, protozoa and fungal zoospores using methods of Galyean (1989) by haemacytometer. One (1) ml of rumen fluid was transferred to a plastic bottle to which 9 ml of 10 ml/L formalin solution (1:9 v/v, rumen fluid: 10 ml/L formalin) was added and then stored at 4°C for measurement of fungal zoospores and the protozoa population. Another 10 ml of the fluid was used for viable

bacteria count (total viable bacteria count) according to the method of Aberu *et al.* (2004). Total viable counts of bacteria were determined in roll tubes on a complete medium, while numbers of cellulolytic bacteria were estimated as the most probable number using a cellulose medium.

Data Analysis

Data collected for all determined parameters were subjected to Analysis of Variance (ANOVA) and differences between treatment means were separated by Least Significance Difference using the General Linear Model procedure of Statistical Analysis System (SAS, 2011).

Results and Discussion

Phytochemical Qualitative Abundance of Leaves of Lactuca taraxacifolia, Phyllanthus amarus and Ocimum gratissimum

Table 1 shows the phytochemical qualitative abundance of leaves of *Lactuca taraxacifolia, Phyllanthus amarus* and *Ocimum gratissimum*. The results showed that there was abundant (high) presence of saponin (+++) in *Lactuca taraxacifolia* and *Ocimum gratissimum*, but was moderately (++) present in *Phyllanthus amarus*. Steroid (+) was relatively present in *Lactuca taraxacifolia* and *Phyllanthus amarus* but was absent (-) in *Ocimum gratissimum.* Tannin (+) was relatively present in *Latuca tarataxifolia* and *Phyllanthus amarus* but was moderately present (++) in *Ocimum gratissimum.* Terpenoid was relatively present in *Lactuca taraxacifolia* but was absent in both *Phyllanthus amarus* and *Ocimum gratissimum.* Flavonoids presence was moderate (++) in *L. taraxacifolia*, relative in *Ocimum gratissimum* and absent in *P.* amarus. Glycoside was only present in *L. taraxacifolia*. Phenol was present (+) in *L. taraxacifolia* and *O. gratissimum*, but absent (-) in *P.* amarus. Oxalate was absent (-) in all the medicinal plants while phytate was only relatively present in *O. gratissimum*

Phytochemicals are biologically active compounds (naturally occurring chemicals in plants), found in trace amounts, which are not established nutrients, but contribute significantly to protection against degenerative diseases and have disease-preventive properties (Ladipo *et al.*, 2010). The presence of tannins, saponins, steroids, flavonoids, cardiac glycosides and terpenoids has also been reported in *L. taraxacifolia* (Adinortey *et al.* (2012). Likewise, Rosine *et al.* (2022) reported the presence of phenols, flavonoids, tannins, anthraquinones, alkaloids, steroids and glycosides and absence of terpenoids and saponins in *Lactuca taraxacifolia.* The high presence of favonoid, glysosides and terpenoids, moderate presence of phenols, tannin and phatates, slight presence of alkanoid, saponin and steroid and the absence of oxalate was reported by Mgbeje *et al.* (2019) in *Ocimum gratissimum*. *Phyllanthus amarus* has been reported to contain tannins, saponins, flavonoids, terpenoids, alkaloids, steroids and glycosides in relative amounts (Alexandra, 2016).

Table 1. Phytochemical Screening of leaves of *Lactuca taraxacifolia* (LT), *Phyllanthus amarus* (PA) and *Ocimum gratissimum* (OG)

Phytoconstituents	LT	PA	OG
Saponin	+++	++	+++
Steroid	+	+	-
Tannin	+	+	++
Alkaloid	+	+	++
Terpenoid	+	-	-
Flavonoid	++	-	+
Glycoside	++	-	-
Phenol	+	-	+
Oxalate	-	-	-
Phytate	-	-	+

Key: present (+), moderately present (++), highly present (+++), not present (-)

Proximate Composition of Lactuca taraxacifolia, Phyllanthus amarus and Ocimum gratissimum

The proximate composition of *Lactuca taraxacifolia, Phyllanthus amarus* and *Ocimum gratissimum* is presented in Table 2. The crude protein (CP) contents of the herbs ranged between 15.87 and 19.44%, the ash content was lowest in ocimum (2.55%) but highest in latuca (20.34%), and crude fibre was also highest for latuca (14.39%). The quantity of CP of above 15 % recorded in the leaves suggests that the leaves have an appreciable amount of protein that may be made available to the rumen microbes which could lead to an increase in the digestibility of the feed, thereby enhances productivity of the ruminant. The crude protein contents obtained in all the leaves study are above the 10-12% recommendation for the growth or maintenance of small ruminants and are also above the minimum threshold level (7% CP) required for optimal rumen microbial activities (Norton, 2003). Carbohydrate contents of *Ocimum gratissimum* obtained in this study is comparable to the value of 66.34 obtained for *Ocimum gratissimum* by Gideon *et al.* (2018) but was higher than the one reported by Akinwumi and Omotayo (2016) of

common vegetables in southwestern Nigeria. Likewise, carbohydrate contents of *Phyllanthus amarus* obtained in this study is higher than the value of 30.56 obtained for *Phyllanthus amarus* by Adinortey *et al.* (2012). This makes *O. gratissimum* and *P. amarus* a good source of energy for animal. Ash contents in *Lactuca taraxacifolia,* being high is an indication of its richness in minerals.

Table 2. Proximate Composition (%) of *Lactuca taraxacifolia, Phyllanthus amarus* and *Ocimum gratissimum*

Parameters	LT	PA	OG
Dry Matter	7.44	10.43	7.96
Crude Protein	19.44	15.87	15.98
Total Ash	20.34	5.73	2.55
Crude Fibre	14.27	7.83	9.85
Crude Fat	0.49	7.02	2.45
Carbohydrate	37.90	53.12	61.21

All the parameters measured for chemical composition of the experimental diets fed to WAD goats were significantly influenced (P<0.05) by dietary treatments (Table 3). The values ranged as follows; crude protein (13.47 – 17.27%), crude fibre (4.89 – 5.94%), ash (4.90 – 6.69%), ether extract (6.79 – 8.51%), carbohydrate (42.76 – 63.51%), Neutral Detergent Soluble NDS (9.57 – 11.41), Acid Detergent Fibre (37.83 – 39.98), Acid Detergent Lignin (29.01 – 30.90), hemicellulose (7.93 – 10.15), cellulose (22.86 – 31.11) and Neutral Detergent Fibre (61.94 – 69.88).

A high dry matter content diets makes the diets a good source of feed for animals in the dry season and will also encourage more feed intake. Moreover, diet containing the mixture of *Ocimum gratissimum*, *phyllantus amarus* and *Lactuca taraxacifolia* (T5) had the highest crude protein (17.27) than the rest of the diets. This suggest that the combination of the 3 herbs in the diet of the goats improved the nutritive capacity of the diets. Similar findings were reported by Amany *et al.* (2022) who also observed that the mixture of herbal plants improved the crude fibre and nutritive value of experimental diets. Diet with *Ocimum gratissimum* (T2) only also had appreciable nutritive value as the CP though slightly lower in value but was statistically similar to that of T5. This suggests that *Ocimum gratissimum* might be considered a veritable protein rich vegetable with potential to serve as substitutes for protein in diet of ruminants especially goats. This is consistent with the findings of Gideon *et al.* (2018) who describes *Ocimum gratissimum* as being very rich in proteins and can serve as substitutes for protein, especially among rural dwellers.

However, T2 had the highest crude fibre content with the least value recorded in T1. This suggests that the herbs especially *Ocimum gratissimum* contain appreciable level of fibre in their composition. There were more of carbohydrate in diets containing herbs compared to control diet with diet T3 having the highest CHO. This indicates that the addition of the herbs to the diets increases the energy content of the diets and thus could use as energy source in goats diet formulation. Fajohunbo and Egbeyale (2010) had earlier reported that carbohydrate is the dominant nutrient in *O. gratissimum* when compared to its crude fibre, ash and crude protein values. Ezeonu *et al.*, (2012) also reported that there is likelihood of prebiotics being contained in *O. gratissimum* as a green leafy vegetable and since prebiotics are carbohydrate complexes, it suggests that the plant could contain a good quantity of some classes of prebiotics. Cellulose and hemicellulose of diet with herbs were higher than the control diet, except in T5 which was similar statistically to control diet. This is expected as the herbs are plant-based feed materials which are expected to be made up of certain levels of cellulose and hemicellulose contents.

Table 3. Chemical Composition (%) of Experimental Diets with the Inclusion of Herbs

Parameters	T1	T2	T3	T4	T5	SEM
Dry matter	92.85^{a}	93.11^{c}	92.99^{b}	93.11^{c}	93.00^{b}	0.0006
Crude Protein	15.75^{ab}	16.08^{ab}	13.47^{c}	15.20^{b}	17.27^{a}	0.6884
Crude Fibre	4.89^{d}	5.94^{a}	5.51^{c}	5.64^{b}	5.67^{b}	0.0008
Ash	4.90^{d}	6.03^{c}	6.69^{a}	6.69^{a}	6.52^{b}	0.0011
Ether Extract	8.51^{a}	7.91^{b}	6.79^{d}	7.06^{c}	7.14^{c}	0.0436
CHO	42.76^{e}	57.15^{c}	63.51^{a}	58.53^{b}	56.41^{d}	0.0780
Neutral Detergent Soluble	11.41^{a}	10.53^{b}	10.82^{b}	9.57^{c}	10.36^{b}	0.0698
Acid Detergent Fibre	39.08^{b}	39.98^{a}	39.94^{a}	38.67^{c}	37.83^{d}	0.0329
Acid Detergent Lignin	30.18^{b}	30.90^{a}	29.43^{c}	29.01^{d}	29.90^{b}	0.0822
Hemicellulose	8.90^{c}	9.09^{b}	10.15^{a}	9.83^{a}	7.93^{c}	0.0822
Cellulose	22.86^{d}	28.31^{c}	29.97^{b}	31.05^{a}	31.11^{a}	0.0102
Neutral Detergent Fibre	61.94^{e}	68.29^{c}	67.93^{d}	69.88^{a}	68.94^{b}	0.0123

^{abcde} Means along the same row with different superscripts are significantly different (P<0.05), SEM = Standard Error of Mean, CHO = carbohydrate, T1 = No herbs (Control), T2 = *Occimum gratissimum*, T3 = *Phyllantus amarus*, T4 = *Lactuca taraxacifolia*, T5 = *P. amarus* + *O. gratissimum* + *L. taraxacifolia*

In vitr Gas Production Pattern of the Experimental Diet

There was non-significant (P>0.05) variation in the gas production pattern of the experimental diets (Table 4). The volume produced under each treatment continue to increase at every three hours. The values for 3 hours incubation period ranged from 8.00 – 9.33 ml/200mg DM and continues to increase till 24th hour from 26.33-36.33 ml/200mg DM among the diets. This trend is an indication that more degradation is still possible after 24 hours of incubation due to rises in the gas at every three hours. Though the production of gas was not significantly (P>0.05) influenced by the incubation period, T1 and T4 diets produced more gas followed by T2 and then T3 while T5 had the least gas production. The production of more gas may be due to higher percentage of cellulose and hemicellulose in T4 diet and higher crude fibre content in *Lactuca taraxacifolia*, than others. Likewise the less gas production as observed in T5 may be due to lesser carbohydrate in the diet when compared with others. Gas production is a function of and a mirror of degradable carbohydrate and therefore, the amount depends on the nature of the carbohydrates (Blummel and Becker, 1997). Many factors may determine the amount of gas produced during fermentation, factor such as the nature and level of fibre, the presence of secondary metabolites and potency of the rumen liquor for incubation (Babayemi *et al.*, 2004). The trend of gas production in this study is consistent with the trend reported by Bunglavan *et al.* (2010) where supplementation of eight different herbs in ruminant diets also led to the continuous production of gas at every four hours incubation.

Table 4. *In vitro* Gas Production Volume of the Experimental Diets at Different Incubation Hours

Incubation hours	Treatments						
	T1	T2	T3	T4	T5	SEM	p-value
3	8.00	9.33	7.33	9.33	7.33	1.30	0.6678
6	15.33	14.00	12.00	16.67	13.33	1.79	0.4452
9	20.67	20.67	16.66	23.33	18.67	2.04	0.2771
12	24.67	24.00	21.33	27.33	22.00	1.63	0.1533
15	26.67	26.00	22.67	29.33	23.33	1.96	0.1878
18	28.67	28.00	26.33	31.33	25.33	2.01	0.3237
21	32.00	28.67	28.00	31.33	25.33	1.55	0.0712
24	36.33	31.33	29.67	34.00	26.33	1.27	0.0022

[abcde] Means along the same row with different superscripts are significantly different (p<0.05), SEM = Standard error mean, T1 = No herbs (Control), T2 = *Occimum gratissimum*, T3 = *Phyllantus amarus*, T4 = *Lactuca taraxacifolia*, T5 = *P. amarus* + *O. gratissimum* + *L. taraxacifolia*

Methane Production of the Experimental Diets

Presented in Figure 1 is the methane production of the experimental diets. There was significant (P>0.05) variation in the methane production. Methane (CH_4) production was highest in control diet T1 than other diets with T5 recording the lowest value. It varies from 7.67 ml/200 mg DM (T5) to 12.67 ml/200 mg DM (T1). The amount of methane produced depends on the level of fermentation. It was observed from this study that experimental diet with high gas production produces more methane. Similar findings have also been reported by and Babayemi and Bamikole (2009) and Ogunbosoye (2016). Methane production is a monumental waste but it is a parameter to measure feedstuff digestibility in the rumen of an animal (Njidda and Nasiru, 2010).

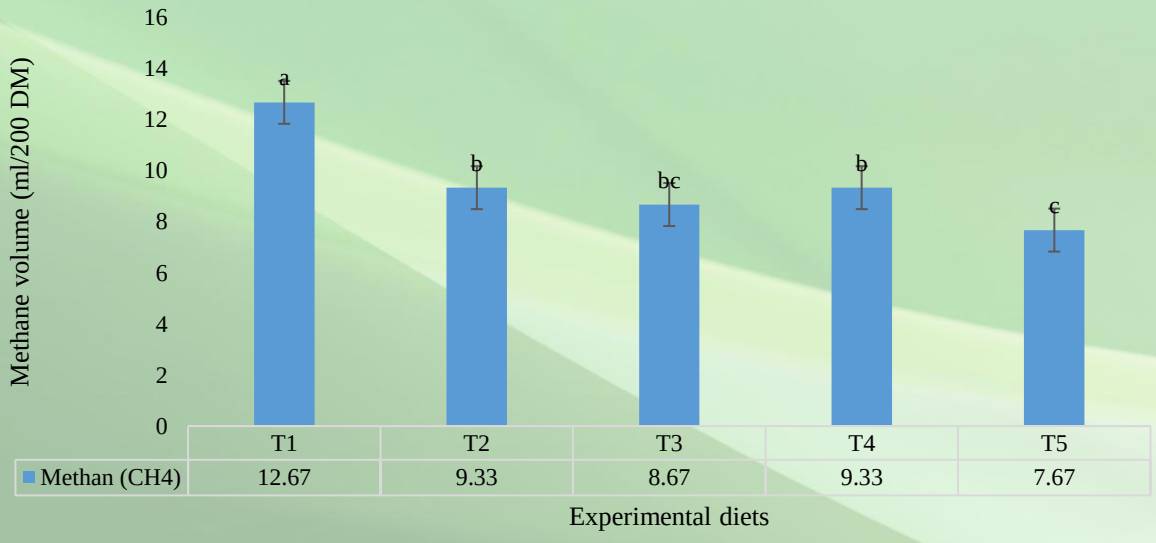


Fig 1. The methane (CH_4) production of experimental diets

Calculated OMD (%), ME (MJ/Kg) and SCFA (µmol) of Experimental Diets

Figures 2, 3 and 4 show the Organic Matter Digestibility (OMD), Metabolizable Energy (ME), and Short Chain Fatty Acids (SCFA) of the experimental diets, resoectively. All the parameters calculated in this study were significantly influenced by the experimental diets. The values for the OMD, ME and SCFA ranged from 48.56 (T5) to 57.45 (T1), 6.99 (T5) to 8.35 (T1) and 0.57 in T5 to 0.81 in T1, respectively. The range value of OMD recorded in this study indicates good digestibility of herbs despite the fact that the control diet recorded the highest digestibility potential. The values of metabolic energy yield reported in this study suggests the potential of the herbs especially *Lactuca taraxacifolia* as energy laden feed additives which can be incorporated in feed formulation for ruminant animals, as animal performance also depends on ME content present in the feed (Niemeläinen *et al.*, 2001). The levels of OMD and ME obtained in this study were similar to 40.12 to 67.06 % (OMD) and 5.58 to 10.32 MJ/Kg (ME) reported by Tag-El-Din *et al.* (2012) in ram.

The low SCFA estimated for T5 might be due to the lower gas production obtained from the diet. The appreciable estimated SCFA in T4 compared to T2, T3 and T5, further suggests the potential of *Lactuca taraxacifolia* to make energy available to the ruminants when consumed. Akinfemi and Ladipo (2014) had earlier reported that SCFA is an indicator of energy availability to the animal. The values of SCFA obtained in this study were slightly higher than the range of 0.23 to 0.60 µmol obtained by Ogunbosoye (2016) on forages fed to ruminant, but was similar to the level of 0.8 – 0.9 µmol reported by Mpanza *et al.* (2020) in ruminant. However, the values were lower than the range values of 6.07 – 6.97 µmol reported by Abd El Tawab *et al.* (2021) in ruminant fed two herbal plants based diets.

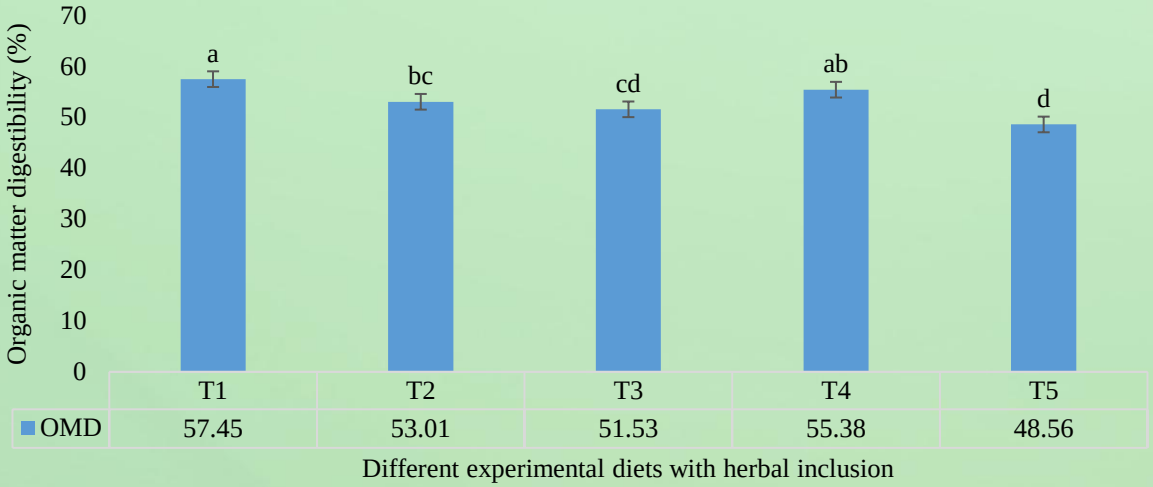


Fig 2. The Organic Matter Digestibility of the Experimental Diet (%)
T1 = No herbs (Control), T2 = *Occimum gratissimum*, T3 = *Phyllantus amarus*, T4 = *Lactuca taraxacifolia*, T5 = *P. amarus* + *O. gratissimum* + *L. taraxacifolia*

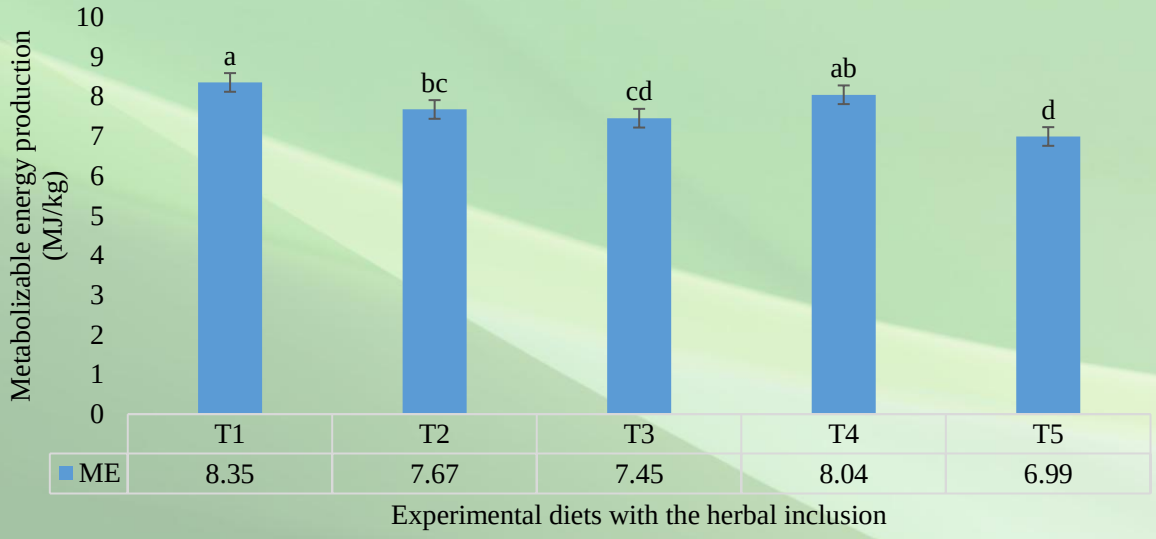


Fig 3. The Metabolisable Energy of the Experimental Diet (MJ/kg)

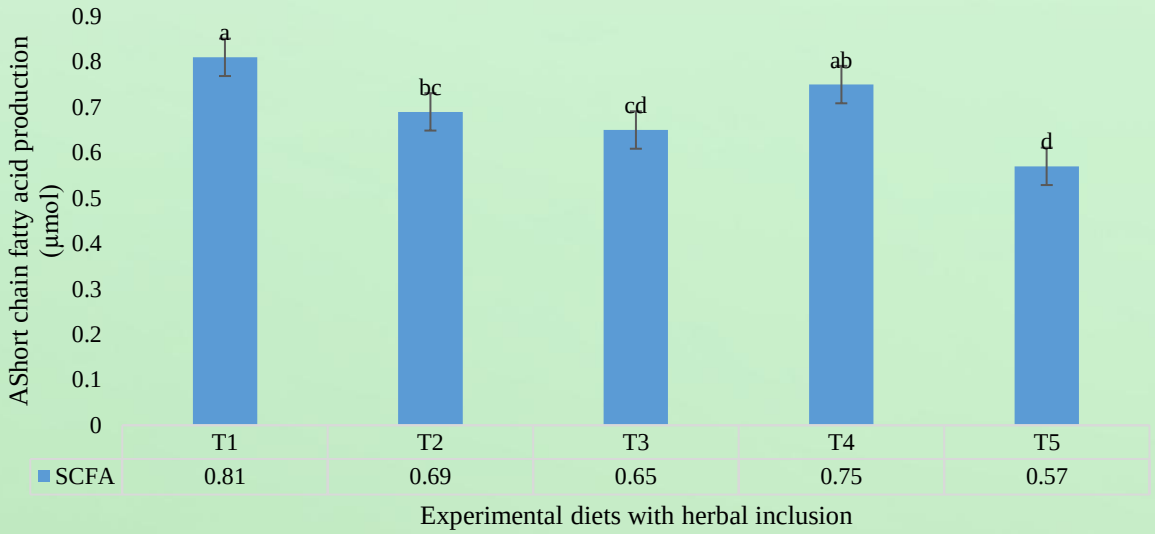


Fig 4.4: The Short Chain Fatty Acid of the Experimental Diet (µmol)

Ruminal Characteristics of West African Dwarf Goats Fed Herbal-Fortified Diets

The effect of different herbal supplementations on the ruminal characteristics of West African dwarf goats is presented in Table 5. All the parameters investigated were significantly ($P<0.05$) influenced by dietary treatments except rumen pH, acetic-propionic ratio (A/P) and rumen ammonia nitrogen (NH_3). The acetic acid values of the goats varied significantly across the treatment groups with goats fed *Phyllantus amarus* (T3) having the highest rumen acetic acid value of 36.45mm/100mL, which is statistically similar to 33.41mm/100mL recorded in goats fed T5, while the values of 28.72, 27.65 and 27.00 mm/100mL obtained in goats fed T2, T1 and T4, respectively were lower and statistically the same. A similar trend was observed in propionic acid content of the rumen. The butyric acid values were higher in all the goats fed the herbal supplements than the control group with goats fed T4 (8.39 mm/100mL) having the highest value, followed by goats on T3 (7.85 mm/100mL), T5 (7.56 mm/100mL) and T2 (7.29 mm/100mL), respectively while control group (5.98 mm/100mL) recorded the least value.

The concentration of acetic acid produced was higher than the concentration of butyric and propionic acid. This is attributed to the fact that cellulolytic bacteria produce acetic acid as major end product from fiber degradation, thus their concentration is always higher than other acids. The range values of acetic acid (27.00 - 36.45 mm/100mL) is lower to the value of 58.5 - 60.2 obtained by Seong *et al.* (2022) but higher than the values of 11.29 – 14.78 obtained by Kurniawati *et al.* (2018) in ruminant fed herbal supplements. The range values of butyric acid (5.98 - 8.39 mm/100mL) and propionic acid (6.52 - 10.42 mm/100mL) obtained in this study are consistent with the values of 5.33 - 5.96 and 9.50 - 11.62 obtained for butyric and propionic acid, respectively by Hassan *et al.* (2021)

Goats on control diet (64.59 mm/100mL), T4 (64.45 mm/100mL) and T2 (64.32 mm/100mL) diet had similar total volatile fatty acid (TVFA) values which were higher than those on T5 (61.00 mm/100mL) and T3 (58.43 mm/100mL) respectively. The range value of 58.43 – 64.45 mm/100mL obtained in this study were lower than the value of 73.14 - 90.57 mm/100mL recorded in goat fed herbal supplement by Wang *et al.* (2023). Rumen pH and TVFA content are essential index for assessing ruminal fermentation (Cui *et al.* 2022). According to Puniya *et al.* (2015), pH range of 5.5 to 6.9 is considered physiologically the normal pH that support normal feed fermentation in the rumen. In this study, supplementation of diet with herbs didn't have significant influence of the ruminal pH, besides the values were slightly lesser than the normal range values, however, TVFA changes significantly, though the values in diets supplemented with herbs were not better than the control diets. This indicates that the herbs supplementation did not improve the energy generation in the rumen of the goats as the herbs might not have aided properly the activities of ruminal cellulolytic bacterial which would have led to increased digestibility of the experimental diets for subsequent energy generation. This may be attributed to the quality of herbs in terms of their constituents and the stage at which they were harvested which might have influenced the way microbes in the rumen acted on them.

It has also been observed that the use of a lower dose of herbal supplement in ruminant diet led to the metabolic redundancy of the ruminal ecosystem, which resulted in lower concentration of TVFA in rumen (Patra *et al.*, 2019). TVFA plays an important role in maintaining and providing energy for the growth of ruminants. The structure, quality, microbial activity, and microflora of ruminant diets has been reported as factors that affect the composition and concentration of TVFA in the rumen (Sun *et al.*, 2019)

Table 5. Effect of Different Herbal Supplementation on Ruminal Characteristics of West African dwarf goats

Parameters	T1	T2	T3	T4	T5	SEM
pH	5.02	5.06	4.48	5.05	4.80	0.10
Acetic acid (mm/100mL)	27.65^{b}	28.72^{b}	36.45^{a}	27.00^{b}	33.41^{ab}	1.32
Butyric acid (mm/100mL)	5.98^{b}	7.29^{ab}	7.85^{ab}	8.39^{a}	7.56^{ab}	0.33
Propionic acid (mm/100mL)	6.69^{ab}	6.90^{ab}	10.42^{a}	6.52^{b}	8.47^{ab}	0.58
TVFA (mm/100mL)	64.59^{a}	64.32^{a}	58.43^{b}	64.45^{a}	61.00^{ab}	0.92
A/P	4.40	4.18	3.56	4.22	4.08	0.18
NH_3-N(mg/100mL)	5.30	5.06	4.48	5.05	4.80	0.10

[a,b] Means along the same row with different superscripts are significantly different (P<0.05), SEM = Standard Error of Mean, TVFA= Total Volatile Fatty Acids, A/P= Acetic acid: Propionic acid, NH_3-N= Rumen ammonia Nitrogen, T1 = No herbs (Control), T2 = *Occimum gratissimum*, T3 = *Phyllantus amarus*, T4 = *Lactuca taraxacifolia*, T5 = *P. amarus + O. gratissimum + L. taraxacifolia*

Effect of Different Herbal Supplementation on the Rumen Microbial Count of West African Dwarf goats

The effect of different herbal supplementation on the rumen microbial count of West African Dwarf goats is presented in Table 6. Herbal supplementation had significant (P<0.05) effect on the microbial population of West African Dwarf goats observed in this study. The total bacterial count, fungal count and protozoan values of the experimental goats ranged from 65.33 - 190.00 × 10^{-4}cfu/mL, 5.67 – 11.00 sfu/mL and 12.67 – 28.67 x10^{-2}/mL respectively.

It is observed that the population of bacteria (190.00) and fungi (11.00) were highest in diet containing the mixture of *P. amarus, O. gratissimum and L. taraxacifolia*. This indicates that herbal mixtures as against sole supplementation perhaps had better impact on the ruminal cellulolytic bacterial activity by multiplying their number to ensure increased digestibility. Moreover, sole supplementation with *P. amarus, O. gratissimum and L. taraxacifolia* also increases the population of bacteria and fungi in the rumen of the goats compared to the control group. The increase population of cellulolytic bacterial is considered a positive impact as the rumen bacteria are known to involve in the degradation of plant polysaccharides to produce VFA as the main source of energy for animals (Mizrahi, 2012). Thus, cellulolytic bacterial activities in the rumen is beneficial to the animal as they help ensure increased digestibility of feed material, ensure availability of nutrient for absorption by the animal. The range values of bacteria obtained in this study were higher than the values of 2.06 – 3.05 obtained in WAD goats fed *O. gratissimum* as reported by Adebayo *et al.* (2019) and higher than 3.1 – 7.6 obtained by Wanapat *et al.* (2013). It is also observed that the population of protozoa were lower in diets supplemented with herbs compared to the control diet except in diet supplemented with *Lactuca taraxacifolia* (T4).

The least protozoa population was recorded in diet supplemented with *P. amarus* (T3). This indicates that other herbs and their combination were able to inhibit the destructive nature of protozoa in the rumen. The secondary plant metabolites in herbs especially saponins have been found to suppress or eliminate protozoa from the rumen and reduce methane and ammonia production (Anantasook and Wanapat, 2012). At appropriate dose, saponins or saponins containing plants have been shown to suppress protozoal population, increase bacteria and fungi population and decrease methanogenesis hence improve performance in ruminants (Sirohi *et al.*, 2009). Lila *et al.* (2003) had earlier reported that the elimination of ciliate protozoa from the rumen reduced methane emission by 30 to 45%. The range value of protozoa population obtained in this study was higher than the value of 4.8 – 7.8 x10^{-2}/mL obtained in ruminant by Wanapat *et al.* (2013) and the higher 0.25 – 0.68 x10^{-2}/mL obtained in WAD goat by Adebayo *et al.* (2019). This also explain why the diet with highest protozoa produced the highest methane.

Table 6. Effect of Different Herbal Supplementation on Rumen Microbial Count of West African Dwarf Goats

Parameters	T1	T2	T3	T4	T5	SEM
Total bacterial count (x10^{-4}cfu/mL)	65.33^{d}	71.67^{cd}	93.33^{b}	75.00^{c}	190.00^{a}	2.83
Total fungal count (sfu/mL)	5.67^{b}	5.83^{b}	9.50^{a}	6.67^{b}	11.00^{a}	0.51
Protozoan (x10^{-2}/mL)	19.00^{b}	13.33^{c}	12.67^{c}	28.67^{a}	17.50^{b}	0.90

SEM = Standard Error of Mean, T1 = No herbs (Control), T2 = *Occimum gratissimum*, T3 = *Phyllantus amarus*, T4 = *Lactuca taraxacifolia*, T5 = *P. amarus + O. gratissimum + L. taraxacifolia*

Conclusion

The results of this study demonstrate that the leaves of *Latuca taraxacifolia*, *Phyllanthus amarus*, and *Ocimum gratissimum* are rich in bioactive compounds, including saponin, tannin, and alkaloid. These phytochemicals significantly impacted methane production, with diets supplemented with *Phyllanthus amarus* and the combination of *Latuca taraxacifolia + Phyllanthus amarus + Ocimum gratissimum* exhibiting substantial reductions in methane production. Furthermore, the studied plant combinations improved ruminal characteristics and significantly modified the microbial population in the rumen, highlighting their potential as natural feed additives for mitigating methane emissions and promoting rumen health.

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Production of Pregelatized Legume Flour From Sortex Rejected Chickpea and White Kidney Bean

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Abstract

The undersized grains in the Sortex rejected part of the legume processing plants have similar nutritional properties with the commercial seeds. Processing these waste legumes and offering them to domestic and foreign markets has the potential to contribute to the country's economy. Therefore, this study was designed to examine the potential of producing relatively higher value-added natural food components from waste legumes with low commercial value. In this study, soaking, boiling and dehulling processes were applied in order to produce flour with different properties from Sortex rejected white kidney beans and chickpeas. Flour samples were obtained from both soaked and boiled (pregelatinized) samples of each legume. The effect of seed coat on the flour quality were also determined. Color, ash, protein, dietary fiber, water absorption capacity and trypsin inhibitor activity were analyzed in these flour samples. According to the total dietary fiber analysis, it was determined that the dietary fiber content of the seed, without seed coat removal, was higher. Pregelatinization process significantly increased the water absorption capacity of flour samples in both legume varieties. While negligible decreases were observed in trypsin inhibitory activity of soaked samples, a significant decrease was detected with pregelatinization process. In general, L* values of flours obtained from white kidney beans and chickpeas increased with soaking process and decreased after pregelatinization. In a* value, decrease was observed with soaking and increase with boiling, and finally, in b* value, decrease was observed with soaking and increase with boiling. High dietary fiber content, low trypsin inhibitory activity and high water absorption capacity were determined as the selection critea of the flours. Therefore, only the samples with the seed coat removed were taken as a potential ingredient for bread production. In bread production experiments, soaked and pregelatinized legume flours were added to wheat flour according to the principle of replacing 20% of the wheat flour. In all bread samples obtained, it was observed that the moisture level of the bread was suitable for the % moisture value requested in the Turkish Food Codex. Volume and baking loss values in breads containing 20% legume flour were found to be similar to the control bread. Although no statistically significant difference was observed, a decrease in the rapidly digestible starch fraction and an increase in the resistant starch fraction were observed in breads containing legume flour. Although it was observed that the sensory scores of the breads produced by mixing legume flours with cereal flours decreased ($p<0.05$) in some parameters, they were still acceptable. As a result, it was determined with this study that innovative food product components with high added value can be produced from legume residues with low commercial value. Turkey is one of the leading countries in legume production. Therefore, the utilization of these wastes has the potential to contribute to the economy.

Key Words: *Legume Flour, Chickpea Flour, Bean Flour, Pregelatinized Flour, Bread*

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Bitkisel Üretimin İklim Değişikliğinden Etkilenebilirliği ve Çözüm Önerisi Olarak Modern Biyoteknolojik Yaklaşımlar

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Özet

Bu çalışmanın amacı, iklim değişikliğinin bitkisel üretim üzerindeki olumsuz etkilerini incelemek ve bu etkileri azaltmak için modern biyoteknolojik yaklaşımların mekanizmalarını ve bitkilerde kullanımlarını ele almaktır. İklim değişikliği, artan sıcaklıklar, kuraklık, aşırı yağışlar ve diğer çevresel stres faktörleri nedeniyle bitkisel üretimde büyük kayıplara yol açmaktadır. Bu durum, gıda güvenliği ve tarımsal sürdürülebilirlik açısından ciddi tehditler oluşturmaktadır. Özellikle, CRISPR-Cas9 ve RNA interference (RNAi) gibi modern biyoteknolojik yöntemler, bitkilerin çevresel streslere karşı dirençli hale getirilmesinde önemli bir rol oynamaktadır. CRISPR-Cas9 teknolojisi, bitkilerin genetik yapısında hassas düzenlemeler yaparak, hastalık-zararlılar, kuraklık, yüksek sıcaklık ve tuzluluk gibi biyotik ve abiyotik faktörlere karşı dayanıklılık sağlamaktadır. RNAi ise, hedef genlerin ekspresyonunu baskılayarak, hastalık direncini artırmak ve çevresel streslere karşı dayanıklılığı güçlendirmek için kullanılmaktadır. Bu biyoteknolojik yaklaşımlar, bitkisel üretimin sürdürülebilirliğini sağlamak ve gıda güvenliğini artırmak için büyük bir potansiyele sahiptir. Ancak, bu kapsamdaki çalışmaların ulusal ve uluslararası daha fazla yaygınlaşması ve desteklenmesi gerekmektedir. İklim değişikliği ile başa çıkabilmek için biyoteknoloji alanındaki araştırmaların artırılması, yenilikçi çözümlerin geliştirilmesi ve tarımda daha geniş bir uygulama alanı bulması önemlidir. Bu alandaki yatırımlar, hem tarımsal verimliliğin artırılmasına hem de çevresel sürdürülebilirliğin sağlanmasına katkıda bulunacaktır.

Anahtar Kelimeler: *Bitkisel üretim, İklim değişikliği, Biyoteknoloji, CRISPR-Cas9, RNAi*

ID: 369

The Effects of Functional Foods on Human Health

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Abstract

Functional foods provide health benefits beyond basic nutrition due to their bioactive compounds. These foods can help prevent chronic diseases, enhance immune function, and improve overall well-being. In recent years, the interest in functional foods has significantly increased due to their potential role in disease prevention and health promotion. Functional foods contain biologically active compounds, such as probiotics, prebiotics, polyphenols, and omega-3 fatty acids, which contribute to improved physiological functions. This study discusses the types of functional foods, their bioactive components, and their effects on human health, focusing on cardiovascular health, gut microbiota, metabolic disorders, and cognitive function. The potential future developments in functional food research are also explored.

Keywords:

Özet

Fonksiyonel gıdalar, biyoaktif bileşikleri sayesinde temel beslenmenin ötesinde sağlık yararları sağlar. Bu gıdalar kronik hastalıkları önlemeye, bağışıklık fonksiyonunu geliştirmeye ve genel refahı iyileştirmeye yardımcı olabilir. Son yıllarda, hastalıkların önlenmesi ve sağlığın geliştirilmesindeki potansiyel rolleri nedeniyle fonksiyonel gıdalara olan ilgi önemli ölçüde artmıştır. Fonksiyonel gıdalar, gelişmiş fizyolojik işlevlere katkıda bulunan probiyotikler, prebiyotikler, polifenoller ve omega-3 yağ asitleri gibi biyolojik olarak aktif bileşikler içerir. Bu çalışma, fonksiyonel gıdaların türlerini, biyoaktif bileşenlerini ve insan sağlığı üzerindeki etkilerini tartışmakta ve kardiyovasküler sağlık, bağırsak mikrobiyotası, metabolik bozukluklar ve bilişsel işleve odaklanmaktadır. Fonksiyonel gıda araştırmalarındaki potansiyel gelişmelerde araştırılmaya devam edilmektedir.

Anahtar kelimeler:

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Lemna minor L. (Duckweed) Importance and Usages

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Abstract

Duckweed (*Lemna minor*) is a plant with a wide range of potential uses in many areas due to its environmental benefits and economic value. This plant is effectively used in bioremediation processes, where it improves water quality by absorbing nitrogen, phosphorus, and other nutrients in water. It also removes toxic substances, such as heavy metals and organic pollutants, from water. In addition to its use in water treatment, duckweed is a valuable feed source for chickens, pigs, fish, and other farm animals due to its high protein content. Its application in biofuel production, enabled by its high starch content, makes it a promising alternative to traditional biofuel sources due to its rapid growth rate and high yield potential. Furthermore, duckweed is evaluated as a soil conditioner and organic fertilizer in agriculture, where it enhances soil fertility through its high nitrogen and phosphorus content. Its application as a soil conditioner and organic fertilizer in agriculture has been demonstrated by its ability to increase soil fertility when dried and ground, thereby supporting plant growth. Furthermore, duckweed has been shown to enhance the water-holding capacity of the soil and increase resistance to drought.

Key Words: *Bioremediation, biofuel, animal feed, Lemna minor*

Lemna minor L. (Su Mercimeği) Önemi ve Kullanım Alanları

Özet

Su mercimeği (*Lemna minor*), çevresel faydaları ve ekonomik potansiyeli nedeniyle birçok alanda geniş kullanım imkânı sunan bir bitkidir. Biyoremediasyon süreçlerinde etkin bir şekilde kullanılan bu bitki, sudaki azot, fosfor ve diğer besin maddelerini absorbe ederek su kalitesini iyileştirir. Aynı zamanda ağır metaller ve organik kirleticiler gibi toksik maddelerin sudan uzaklaştırılmasını sağlar. Yüksek protein içeriği ile tavuklar, domuzlar, balıklar ve diğer çiftlik hayvanları için değerli bir yem kaynağıdır. Biyoyakıt üretimi için de potansiyel bir kaynak olan su mercimeği, yüksek nişasta içeriği sayesinde biyoetanol üretiminde kullanılabilir. Hızlı büyüme oranı ve yüksek verim potansiyeli ile geleneksel biyoyakıt kaynaklarına alternatif olarak kabul edilmektedir. Tarımda toprak düzenleyici ve organik gübre olarak değerlendirilen su mercimeği, yüksek azot ve fosfor içeriği ile toprağın besin değerini artırmaktadır. Kurutulmuş ve öğütülmüş su mercimeği uygulamaları, toprağa ilave edildiğinde toprağın verimliliğini artırmakta ve bitki büyümesini desteklemektedir. Ayrıca toprağın su tutma kapasitesini de artırarak kuraklığa karşı direnci artırmaktadır.

Anahtar Kelimeler: *Biyoremediasyon, biyoyakıt, hayvan yemi, Lemna minor*

Giriş

Dünya genelinde, su mercimeği üzerine birçok araştırma ve proje yürütülmektedir. Özellikle, biyoremediasyon, biyoyakıt üretimi ve hayvan yemi olarak kullanımı üzerine odaklanan çalışmalar, su mercimeğinin potansiyelini ortaya koymaktadır. ABD, Çin ve Hindistan gibi ülkelerde, su mercimeği kullanılarak atık su arıtma sistemleri geliştirilmiş ve bu sistemler endüstriyel ve tarımsal atık suların temizlenmesinde başarılı sonuçlar vermiştir. Ayrıca, Avrupa Birliği tarafından finanse edilen projelerde, su mercimeğinden biyoyakıt üretimi üzerine çalışmalar yapılmaktadır. Bu projeler, su mercimeğinin sürdürülebilir bir enerji kaynağı olarak kullanılmasını hedeflemektedir (Cheng ve Stomp, 2009; Xu ve Shen, 2011).

Türkiye'de, su mercimeği üzerine yapılan çalışmalar henüz yeni yeni gelişmektedir. Ancak, son yıllarda, su mercimeğinin biyoremediasyon, hayvan yemi ve biyoyakıt üretimi gibi alanlarda kullanımı üzerine araştırmalar artmaktadır. Özellikle, üniversiteler ve araştırma enstitüleri tarafından yürütülen projeler, su mercimeğinin Türkiye'deki potansiyelini ortaya koymaktadır. Örneğin, bazı üniversitelerde, su mercimeği kullanılarak atık su arıtma sistemleri geliştirilmiş ve bu sistemler, tarımsal ve endüstriyel atık suların temizlenmesinde başarılı sonuçlar vermiştir. Ayrıca, su mercimeğinin hayvan yemi olarak kullanımı üzerine yapılan çalışmalar, bitkinin çiftlik hayvanları için değerli bir besin kaynağı olduğunu göstermiştir (Takács ve ark., 2025).

Su mercimeği, sadece çevresel faydaları ile değil, aynı zamanda ekonomik potansiyeli ile de dikkat çekmektedir. Bu bitki, hızlı büyüme oranı, yüksek protein içeriği ve biyoremediasyon yetenekleri ile sürdürülebilir tarım ve endüstriyel uygulamalar için önemli bir kaynak olarak kabul edilmektedir. Bu nedenle, su mercimeği üzerine yapılan araştırmalar hem çevresel sorunların çözümüne hem de ekonomik fırsatların değerlendirilmesine katkı sağlamaktadır.

Su Mercimeğinin Yapısı, Büyüme Döngüsü ve Üreme Şekli

Lemna cinsi, yaygın olarak su mercimeği olarak bilinen, Lemnaceae familyasına ait küçük, yüzen su bitkileridir. Su mercimeği, basit yapılı bir bitki olup, her bir bitki bir veya birkaç yapraksı yapıdan oluşmaktadır. Bu yapılar, su yüzeyinde yüzer ve fotosentez için gerekli olan klorofil içerir. Su mercimeği, kök benzeri yapılar (rizoidler) ile suda dengede durur, ancak bu yapılar gerçek kökler değildir ve besin alımından çok denge sağlamaya yöneliktir (Coşkun et al, 2018).

Su mercimeği, vejetatif üreme yoluyla hızla çoğalmaktadır. Bu üreme şeklinde, ana bitkiden ayrılan yeni yapraksı yapılar, bağımsız bitkiler haline gelmektedir. Bu süreç, uygun koşullarda çok hızlı gerçekleşmekte ve su mercimeği popülasyonları kısa sürede büyük alanlara yayılmaktadır. Ayrıca, bazı *Lemna* türleri, çiçekli bitkiler olmalarına rağmen, çiçeklenme ve tohum üretimi nadiren gözlenmektedir (Landolt, 1986).

Su Mercimeğinin Doğal Ekosistemlerdeki Rolü ve Diğer Canlılarla İlişkisi

Su mercimeği, doğal ekosistemlerde önemli bir rol oynamaktadır Su yüzeyinde yoğun bir şekilde büyüyerek, suyun ışık geçirgenliğini azaltmakta ve bu da su altı bitkilerinin büyümesini sınırlayabilmektedir. Ancak, su mercimeği aynı zamanda sucul ekosistemlerdeki besin döngüsüne katkıda bulunmaktadır. Özellikle, azot ve fosfor gibi besin maddelerini sudan alarak, suyun besin yükünü azaltmakta ve bu da ötrofikasyonun önlenmesine yardımcı olmaktadır (Zimmo ve ark., 2004).

Bu bitki, sucul ekosistemlerdeki birçok canlı için önemli bir besin kaynağıdır. Balıklar, su kuşları ve diğer sucul organizmalar, su mercimeği ile beslenmektedir. Ayrıca, su mercimeği, mikroorganizmalar için bir yaşam alanı sağlamakta ve sucul ekosistemlerdeki biyolojik çeşitliliği desteklemektedir (Sulaiman ve ark., 2025).

Su Mercimeği Yetiştirme Koşulları ve Yöntemleri

Su Kalitesi, Sıcaklık, Işıklanma ve Besin Gereksinimleri

Su mercimeği yetiştiriciliği için uygun bir ortam sağlamak, bitkinin sağlıklı büyümesi ve yüksek verim elde edilmesi açısından kritik öneme sahiptir. Su mercimeği, genellikle tatlı su kaynaklarında yetişmekte, su kalitesini ve büyüme durumunu doğrudan etkilemektedir. Suyun pH değeri, 6.0-7.5 aralığında olmalıdır. Ayrıca, suda yeterli miktarda azot (N) ve fosfor (P) bulunması, bitkinin hızlı büyümesini sağlamaktadır (Cheng ve Stomp, 2009).

Sıcaklık, su mercimeği yetiştiriciliğinde önemli bir faktördür. Optimum büyüme sıcaklığı, 20-30°C aralığındadır. Sıcaklığın bu aralığın altına düşmesi, büyüme hızını yavaşlatırken, yüksek sıcaklıklar ise bitkinin stres altına girmesine neden olmaktadır (Baek ve ark., 2021)

Işıklanma, su mercimeğinin fotosentez yapması için gereklidir. Bitki, günde en az 12-16 saat ışık almalıdır. Doğal güneş ışığı, en iyi büyüme sonuçlarını sağlamaktadır. Fakat yapay ışıklandırma sistemleri de kullanılabilir. Işık yoğunluğu, 1000-2000 lux aralığında olmalıdır (Petersen, 2022).

Besin ihtiyacı açısından, su mercimeği azot ve fosfor gibi makro besinlerin yanı sıra potasyum, kalsiyum ve magnezyum gibi mikro besinlere de ihtiyaç duymaktadır. Bu besinler, bitkinin hızlı büyümesi ve yüksek verim elde edilmesi için gereklidir (Xu ve Shen, 2011).

Su Mercimeği Yetiştirme Teknikleri ve Saklama Koşulları

Su mercimeği, çeşitli yetiştirme sistemlerinde yetiştirilebilir. Laboratuvar ortamında, kontrollü koşullar altında su mercimeği yetiştirilerek, bitkinin büyüme parametreleri ve besin gereksinimleri üzerine detaylı çalışmalar yapılabilir. Laboratuvar ortamında, su mercimeği genellikle cam kaplar veya plastik kaplar içinde yetiştirilmekte ve suyun sıcaklığı, pH'ı ve besin içeriği sürekli olarak izlenmektedir (Pagliuso ve ark., 2022).

Açık havuzlarda su mercimeği yetiştiriciliği, daha büyük ölçekli üretim için uygundur. Bu yöntemde, su mercimeği, doğal veya yapay olarak oluşturulmuş havuzlarda yetiştirilir. Havuzların derinliği genellikle 20-50 cm arasında değişir ve suyun sürekli olarak karıştırılması, bitkinin homojen bir şekilde büyümesini sağlar. Açık havuzlarda yetiştiricilik, düşük maliyetli bir yöntemdir, ancak çevresel faktörler (sıcaklık, yağış gibi) bitkinin büyümesini etkileyebilir (Anim ve ark., 2025).

Diğer yetiştirme sistemleri arasında, kapalı sistemler (biyoreaktörler vs.) ve yüzen platformlar bulunur. Kapalı sistemler, su mercimeğinin kontrollü koşullar altında yetiştirilmesini sağlamakta ve bu da yüksek verim elde edilmesine olanak tanımaktadır. Yüzen platformlar ise, su mercimeğinin doğal su kaynaklarında yetiştirilmesi için kullanılmaktadır ve bu yöntem, suyun kalitesini iyileştirmek amacıyla da değerlendirilebilir (Cheng ve Stomp, 2009).

Su mercimeği, hızlı büyüme oranı nedeniyle kısa sürede hasat edilebilmektedir. Hasat zamanı, bitkinin büyüme hızına ve yetiştirme koşullarına bağlı olarak değişmektedir. Genellikle, su mercimeği, 5-7 günlük bir büyüme

periyodundan sonra hasat edilebilir. Hasat işlemi, bitkinin su yüzeyinden toplanması şeklinde gerçekleştirilir. Bu işlem, elle veya mekanik yöntemlerle yapılabilir. Hasat edilen su mercimeği, çeşitli şekillerde saklanabilir. Taze olarak kullanılacak su mercimeği, buzdolabında birkaç gün saklanabilir. Uzun süreli saklama için, su mercimeği kurutulabilir veya dondurulabilir. Kurutulmuş su mercimeği, öğütülerek toz haline getirilebilir ve bu toz, hayvan yemi veya gübre olarak kullanılabilir. Dondurulmuş su mercimeği ise, daha sonra kullanılmak üzere saklanabilir (Cheng ve Stomp, 2009).

Su Mercimeğinin Kullanım Alanları

Biyoremediasyon

Su mercimeği biyoremediasyon süreçlerinde oldukça etkili bir şekilde kullanılabilen bir bitkidir. Bu bitki, sudaki azot, fosfor ve diğer besin maddelerini absorbe ederek su kalitesini önemli ölçüde iyileştirebilir. Ayrıca, su mercimeği, ağır metaller (kurşun, kadmiyum, cıva vb.) ve organik kirleticiler (pestisitler, endüstriyel kimyasallar vb.) gibi toksik maddeleri de sudan uzaklaştırabilir. Bu özellikleri nedeniyle, su mercimeği, atık su arıtma tesislerinde ve kirletilmiş su kaynaklarının temizlenmesinde yaygın olarak kullanılmaktadır (Zimmo ve ark., 2004). Yang (2022) tarafından yapılan bir araştırmada, su mercimeğinin pestisitler gibi organik kirleticileri sudan %80 oranında uzaklaştırabildiği belirtilmiştir. Bu bulgular, su mercimeğinin organik kirleticilerin giderilmesinde de oldukça etkili olduğunu göstermektedir. Ayrıca, Smith ve Moelyowati (2021) tarafından yapılan bir çalışmada, su mercimeğinin endüstriyel atık suların arıtılmasındaki rolü incelenmiş ve bitkinin azot ve fosfor gideriminde oldukça etkili olduğu raporlanmıştır. Bu çalışma, su mercimeğinin biyoremediasyon süreçlerindeki önemini ve çeşitli kirleticilerin giderilmesindeki etkinliğini ortaya koymaktadır. Su mercimeği, özellikle atık su arıtma ve kirletilmiş su kaynaklarının temizlenmesi gibi alanlarda çevre dostu bir çözüm olarak kullanılmaya devam etmektedir.

Hayvan Yemi

Su mercimeği (*Lemna* spp.), yüksek protein içeriği (%20-45) ve zengin besin profili nedeniyle hayvan yemi olarak yaygın bir şekilde kullanılmaktadır. Bitki, amino asitler, vitaminler (örneğin, A, B, C vitaminleri) ve mineraller (kalsiyum, magnezyum, demir gibi) açısından oldukça zengin bir kaynaktır. Bu özellikleriyle su mercimeği, tavuklar, domuzlar, balıklar ve diğer çiftlik hayvanları için değerli bir yem alternatifi sunmaktadır. Hayvanlar üzerinde yapılan çalışmalar, su mercimeği ile beslenen hayvanların büyüme performansının arttığını ve bağışıklık sistemlerinin güçlendiğini göstermiştir (Leng ve ark., 1995). Mwale ve Gwaze (2023) tarafından yapılan bir çalışmada, su mercimeği ile beslenen tavukların büyüme performansının %15-20 oranında arttığı belirtilmiştir. Bu çalışma, su mercimeğinin kümes hayvanları için besleyici bir yem kaynağı olduğunu kanıtlamıştır. Takács ve ark. (2025) tarafından yürütülen bir araştırmada ise, su mercimeğinin domuz yeminde kullanımının, hayvanların bağışıklık sistemini güçlendirdiği ve hastalık direncini artırdığı vurgulanmıştır. Bu bulgular, su mercimeğinin domuz yetiştiriciliğinde sağlık ve performans açısından önemli faydalar sağladığını ortaya koymaktadır. Bir başka çalışmada ise, su mercimeği ile beslenen balıkların büyüme hızının %25 oranında arttığı ve yem maliyetlerinin düştüğü raporlanmıştır (Sosa ve ark., 2024). Bu çalışma, su mercimeğinin su ürünleri yetiştiriciliğinde hem ekonomik hem de besin içeriği açıdan avantajlar sağladığını ortaya koymuştur. Yürütülen çalışmalar, su mercimeğinin hayvan yemi olarak kullanımının, hayvanların büyüme performansını artırmanın yanı sıra bağışıklık sistemlerini de güçlendirdiği ve yem maliyetlerini düşürme gibi önemli faydalar sağladığını ortaya koymaktadır. Bu nedenle su mercimeği, sürdürülebilir hayvancılık uygulamaları için değerli bir kaynak olarak ön plana çıkmaktadır.

Biyoyakıt Üretimi

Su mercimeği biyoyakıt üretimi için potansiyel bir kaynak olarak kabul edilmektedir. Bitki, yüksek nişasta içeriği nedeniyle biyoetanol üretiminde kullanılabilir. Biyoetanol üretimi için, su mercimeği önce fermente edilir ve ardından damıtma işlemi ile etanol elde edilir. Su mercimeği, hızlı büyüme oranı ve yüksek verim potansiyeli nedeniyle, geleneksel biyoyakıt kaynaklarına (örneğin, mısır, şeker kamışı) alternatif olarak görülmektedir. Ayrıca, su mercimeği yetiştiriciliği, tarım arazileri üzerinde baskı oluşturmadan gerçekleştirilebilir, bu da onu sürdürülebilir bir enerji kaynağı haline getirmektedir (Xu ve Shen, 2011). Son yıllarda yapılan çalışmalar, su mercimeğinin biyoyakıt üretimindeki potansiyelini daha da detaylı bir şekilde ortaya koymuştur. Cui ve ark. (2020) tarafından yapılan bir çalışmada, su mercimeğinin yüksek nişasta içeriği nedeniyle verimli bir biyoyakıt kaynağı olduğu vurgulanmıştır. Başka bir çalışma su mercimeğinin yağ içeriğinin yüksek olduğunu ve biyodizel üretimi için değerli bir kaynak olabileceğini ortaya koymuştur (Krzywonos et al. 2023). Chusov ve ark. (2022) tarafından ise su mercimeğinin biyogaz üretimindeki etkinliği araştırılmış ve bitkinin yüksek organik madde içeriği nedeniyle verimli bir kaynak olduğu bildirilmiştir. Biyoetanol, biyodizel ve biyogaz gibi farklı biyoyakıt türlerinin üretimi için potansiyel bir kaynak olan su mercimeği, hızlı büyüme oranı, yüksek verimliliği ve tarım arazileri üzerinde baskı oluşturmaması nedeniyle sürdürülebilir bir enerji kaynağı olarak dikkat çekmektedir.

Su Ürünleri Yetiştiriciliği

Su mercimeği, balıklar ve diğer su canlıları için zengin bir besin kaynağıdır. Özellikle tilapia, sazan ve somon gibi balık türleri, su mercimeği ile beslenmektedirler. Bu bitki, balıkların büyüme hızını artırmakta ve bağışıklık sistemlerini güçlendirmektedir. Ayrıca, su ürünleri yetiştiriciliğinde kullanılan yem maliyetlerini düşürerek ekonomik olarak avantaj sağlamaktadır (Leng ve ark., 1995). Opiyo ve ark. (2022) tarafından yapılan bir çalışmada, su mercimeği ile beslenen tilapia balıklarının büyüme hızının %20 oranında arttığı gözlenmiştir. Su mercimeği ile yürütülen bir başka çalışmada ise, sazan balıklarının bağışıklık sisteminin güçlendiği, böylece hastalık direncini artırdığı belirlenmiştir (Goswami ve ark., 2022). Jaimes Prada ve ark. (2024) tarafından yapılan bir çalışmada ise, su mercimeği ile beslenen balıkların yem maliyetlerinin önemli ölçüde düştüğü, ekonomik bir yem alternatifi olarak kullanılabileceği saptanmıştır.

Tarım

Su mercimeği (*Lemna* spp.), tarımda toprak düzenleyici ve organik gübre olarak kullanılabilen önemli bir bitkidir. Bitki, yüksek azot ve fosfor içeriği nedeniyle toprağın besin değerini artırmaktadır. Kurutulmuş ve öğütülmüş su mercimeği, toprağa karıştırılarak kullanılabilmektedir. Bu uygulama, toprağın verimliliğini artırmakta ve bitkilerin büyümesini desteklemektedir. Ayrıca, su mercimeği, toprağın su tutma kapasitesini artırarak kuraklığa karşı direnci de artırmaktadır (Xu ve Shen, 2011). Fernandez Pulido ve ark. (2024) tarafından yürütülen bir çalışmada, su mercimeği ile gübrelenen topraklarda bitki büyümesinin önemli ölçüde arttığı vurgulanmıştır. Baldi ve ark. (2025) yılında yürüttükleri çalışmalarında su mercimeğinin özellikle kurak bölgelerde toprağın su tutma kapasitesini artırarak tarımsal üretimi iyileştirdiğini ortaya koymuşlardır. Benzer sonuçlar Thingujam ve ark. (2024) tarafından yürütülen çalışma sonucunda da elde edilmiştir.

Sonuç

Su mercimeği, çevresel ve ekonomik açıdan önemli bir potansiyele sahiptir. Bitki, biyoremediasyon, hayvan yemi, biyoyakıt üretimi ve tarım gibi farklı alanlarda kullanılabilmektedir. Gelecekte, su mercimeği üzerine yapılacak araştırma ve geliştirme çalışmaları, bitkinin kullanım alanlarını artırabilir ve sürdürülebilir bir kaynak olarak değerini iyileştirebilir. Özellikle, su mercimeğinin genetik mühendisliği yöntemleri ile iyileştirilmesi, bitkinin büyüme hızını ve besin içeriğini de artırabilir. Ayrıca, su mercimeğinin endüstriyel ölçekte yetiştirilmesi ve işlenmesi için yeni teknolojilerin ortaya konması bitkinin ticari değerini de artıracaktır. Su mercimeği yetiştiriciliği yaparken su kalitesinin de takip edilmesi gerekmektedir. Böylelikle bitki için ideal olan su pH'sı, sıcaklığı, besin içeriği sağlanmış olacaktır. Ayrıca uygun büyüme döngüsünde bitkiler hasat edilip, uygun koşullarda saklanmalıdır. Su mercimeği yetiştiriciliği yaparken doğal ekosistemler üzerinde olumsuz etkiler yaratabilecek olmasından dolayı çevresel etkilerde göz önünde bulundurulmalıdır. Su mercimeğinin kullanım alanları ve yetiştiriciliği konusunda çiftçiler, araştırıcılar ve diğer paydaşlar bilinçlendirilmelidir. Bu, su mercimeğinin daha yaygın bir şekilde kullanılmasını sağlayabilir. Sonuç olarak, su mercimeği, çevresel ve ekonomik açıdan büyük bir potansiyele sahiptir. Doğru yetiştirme ve kullanım yöntemleri ile su mercimeği, sürdürülebilir bir kaynak olarak değerlendirilebilir ve gelecekte birçok alanda kullanılabilir.

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Exploring development, growth, yield and water use of several crops under climate change with LINTUL-MULTICROP, a statistical and mechanical simulation

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Abstract

Initially, a LINTUL crop growth model version was developed, validated, and applied to explore the effects of global warming on potato crop yield.With seven crops (wheat, soy, maize, cotton, sugar beet, rice, and potatoes) being used as an example in the case of Türkiye, the study aimed to broaden the applicability of the most recent LINTUL model to additional crops. The model's inputs include the present dates of planting or sowing and harvest for each crop in a relevant cropping ecology, the base temperature below which no development takes place, the number of degree days between planting and emergence and between emergence and full ground cover, the harvest index, the efficiency of radiation use, and the dry matter amount of the produce. By 2050, it was projected that the parameter values for climate change-related inputs will result in a 2°C rise in temperature and a 200 ppm rise in CO_2 concentration. The model investigated variations in agricultural productivity and water usage with and without adaptation, such as adjusting each crop's growth season. The latest version of the LINTUL model predicts that the wheat crop would have a shorter season for growth and decreased yields in the 2050s, whereas the other plants under investigation will have a longer growing season and better yields. Wheat, rice, soybeans, and sugar beet will all require more irrigation, but cotton, potatoes, and other cotton-related crops would require less irrigation. The future projections of seven economically important crops for Türkiye should be used by producers, the industry, and policymakers worldwide to plan, invest in, develop, and prevent the negative consequences of climate change.

Keywords: *LINTUL, modelling, yield, temperature, CO_2, crop, climate change, wheat, soya, maize, cotton, sugar beet, rice, potato*

ID: 373

Comparative Analysis of Drying Techniques to Assess the Shelf Life Extension of Apple Varieties

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Abstract

This study investigates the comparative efficacy of two dehydration methods, solar tunnel drying and hot air cabinet drying, in enhancing the shelf life of three apple cultivars: Gala, Red Delicious, and Golden Delicious. Drying processes were conducted over intervals of 12, 15, 18, 21, and 24 hours to identify the optimal drying duration for each method and cultivar. Both techniques significantly reduced moisture content, thereby extending shelf life; however, notable differences in drying efficiency and product quality were observed. Hot air cabinet drying, characterized by consistent and controlled environmental conditions, facilitated a more uniform reduction in moisture content. Treatment T5 (hot air cabinet, 24 hours) consistently achieved the lowest moisture content across all time points, whereas, T6 (solar tunnel, 12 hours) exhibited the highest residual moisture levels but demonstrated superior preservation of nutritional constituents, particularly minerals. Hot air cabinet drying also maintained the apples' original color and flavor more effectively, benefiting from its independence from solar radiation variability. In contrast, solar tunnel drying was more cost-effective and environmentally friendly. Optimal drying times varied by cultivar: Red Delicious and Gala required 12-15 hours (hot air) and 24 hours (solar tunnel), whereas, Golden Delicious achieved optimal results at 18 hours (hot air) and 21 hours (solar tunnel). The study concludes that hot air cabinet drying for 15 hours is most effective for maximizing shelf life and quality, yielding moisture contents of 12.2% for Golden Delicious, 13.0% for Red Delicious, and 11.5% for Gala. These findings underscore the trade-offs between drying efficiency, product quality, and environmental sustainability, providing valuable insights for optimizing dehydration processes in apple preservation.

Keywords: *Apple; Drying, Hot air drying, Solar drying, Shelf life extension, Environmental Sustainability*

ID: 374

Level of Utilization of Agritech Services by Rice Farmers in Niger State, Nigeria

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Abstract

The integration of technology into agriculture has significantly transformed farming practices. However, many farmers still rely on traditional methods, limiting their productivity. This study assesses the level of utilization of agritech services by rice farmers in Niger State, Nigeria. A multistage sampling technique was employed to select 120 respondents from three local government areas. Data were collected using structured questionnaires and analyzed using descriptive statistics, correlation, and chi-square tests. Findings revealed farming experience had a significant positive correlation with the level of agritech utilization ($r = 0.303$, $p = 0.001$). The chi-square analysis indicated a significant association between gender and agritech utilization ($\chi^2 = 4.335$, $p = 0.037$), with male farmers demonstrating a higher level of adoption compared to female farmers. The study highlights the need for targeted awareness campaigns and institutional support to enhance agritech adoption, particularly among female and less-experienced farmers, to improve agricultural productivity.

Keywords: *Agritech, Rice Farmers, Agricultural Production, Technology Adoption, Niger State.*

ID: 375

Protective Community Index as a Measure for Child Labour: A Case Study of Cocoa-Producing Communities in Idanre Local Government Area, Ondo State

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Abstract

This study investigated the Protective Community Index (PCI) of cocoa-producing communities in the Idanre Local Government Area of Ondo State, Nigeria. The Protective Community Index serves as a tool for evaluating community resilience and child protection mechanisms, especially in the context of child labor. This study ascertained the socioeconomic characteristics of respondents, determined the level of children's involvement in cocoa production activities, identified the availability of social amenities, and identified the available supporting welfare structures that protect and support children in cocoa-producing communities. Primary data were collected through purposive sampling from 168 respondents, including community leaders, cocoa farmers, teachers, and children across eight cocoa-producing communities. Structured questionnaires were used to gather accurate information. Data analysis involved descriptive statistics, such as frequency, percentage, and mean, alongside inferential statistics, including Pearson Product Moment Correlation, to test hypotheses at a significance level of $p < 0.05$. PCI was measured using a tool developed by the International Cocoa Initiative (ICI). The findings revealed that The Protective Community Index (PCI) of the studied communities was moderate (57.6%). Cocoa farming and community leadership were dominated by middle-aged and older men, while teaching roles comprised a female majority (73.2%). Child labor, although not prevalent in hazardous activities, was linked to a school absenteeism rate of 5.4%. Children's involvement in cocoa farming activities was low, with an average (mean) participation score of 16.74. The study also highlighted the inadequacies in social amenities, such as water and healthcare, and insufficient welfare structures, including scholarships and feeding programs. This study emphasizes the need for increased youth engagement in agriculture, gender equality in leadership roles, improved access to quality education, and enhanced social amenities to foster child protection and sustainable community development.

Key words: *Protective Community Index, child labor, cocoa production, social amenities, welfare systems*

Introduction

Child labor remains a critical global issue with profound social, economic, and ethical implications. Work deprives children of their childhood, interferes with their education, and jeopardizes their physical and mental well-being (ILO, 2020). According to UNICEF, sub-Saharan Africa has the highest prevalence of child labor, with over 70% of these children working in agriculture, often under hazardous conditions (UNICEF 2023). Cocoa farming, as a major sector in agriculture, has consistently drawn attention for its reliance on child labor. Addressing child labor in cocoa-producing regions is essential not only for protecting children's rights, but also for ensuring sustainable agricultural development. In Nigeria, a significant cocoa producer, the issue persists, particularly in rural communities such as the Idanre Local Government Area in Ondo State. This study focused on understanding the protective mechanisms available within these communities and offered a pathway for informed interventions.

Previous studies have extensively documented the prevalence and drivers of child labor in cocoa-producing regions. Numerous studies have focused on countries such as Côte d'Ivoire and Ghana, which together account for nearly 60% of the global cocoa supply. Reports indicate that over 1.5 million children are engaged in hazardous activities on cocoa farms in these countries, driven by poverty, inadequate access to education, and entrenched cultural norms (Human Rights Watch, 2020; NORC, 2020). These studies have provided valuable insights into the socioeconomic conditions that perpetuate child labor. However, they often neglect the role of community resilience and protective structures, which are crucial for mitigating risks and supporting child welfare. The introduction of the Protective Community Index (PCI) by the International Cocoa Initiative (ICI) represents a significant step toward addressing this gap. The PCI serves as a tool to evaluate the resilience of cocoa-growing communities, focusing on access to education, healthcare, and social infrastructure that can reduce child labor risks (ICI, 2023). Despite its potential, there have been limited applications of the PCI framework in Nigerian cocoa-producing communities, highlighting a critical gap in the literature.

The issue of child labor in cocoa-producing communities in Nigeria, is compounded by several systemic challenges. These include insufficient social amenities such as clean water and healthcare facilities, weak enforcement of child labor laws, and cultural practices that normalize children's involvement in farming activities. Although child labor contributes to immediate family income, it comes at a significant cost to children's education, health, and future opportunities. Studies suggest that strengthening community-based protective structures can play a pivotal role in reducing vulnerability (ILO, 2020; UNICEF, 2023). Therefore, this study aims to address this knowledge gap by investigating the protective mechanisms within Idanre's cocoa-producing communities and evaluating their effectiveness using the PCI framework. This study distinguishes itself from previous studies by focusing on the resilience and protective capacity of communities rather than merely documenting the prevalence of child labor. Specifically, it evaluates the availability and quality of social amenities and welfare systems within the cocoa-producing communities. By assessing these factors through the PCI lens, this study aimed to provide actionable insights for stakeholders, including policymakers, non-governmental organizations, and community leaders, to design targeted interventions that enhance child protection and foster sustainable community development. This study addresses a critical gap in the literature by focusing on the protective capacity of the cocoa-producing communities in Nigeria. The application of PCI seeks to illuminate pathways to reduce child labor risks and improve community resilience. The findings are expected to contribute significantly to the discourse on child labor, providing evidence-based recommendations for creating safer and more supportive environments for children in agricultural settings.

Materials and Methods

Study Area

This study was conducted in the Idanre Local Government Area, Ondo State, Nigeria, which is a significant cocoa-producing region in the southwestern part of the country, Nigeria. Ondo State is the largest cocoa producer in Nigeria and contributes significantly to its cocoa exports. Idanre, in particular, is characterized by its extensive cocoa farms and rural communities, where cocoa farming serves as the primary source of livelihood. The local climate, with distinct rainy and dry seasons, supports the cultivation of cocoa.

Population of the Study

The target populations were all cocoa-producing communities, including community leaders, farmers, teachers, and children, within the selected communities in the Idanre. These groups of people were chosen to provide diverse perspectives on child labor and community resilience.

Sampling Techniques (Sampling Procedure & Size)

A purposive sampling method was employed to select the respondents. Idanre Local Government Area was selected because of its prominence in cocoa production in the state. Eight cocoa-producing communities within Idanre were purposively selected to represent the area's cocoa-farming activities based on production capacities. Subsequently, 21 respondents were selected from each community, comprising one community leader, five teachers, five cocoa farmers, and ten children aged 5 to 17 years. This approach ensured representation across key stakeholders, resulting in a sample size of 168 respondents.

Method of Data Collection

Primary data were collected using structured questionnaires designed to gather information on the socioeconomic characteristics, level of children's involvement in cocoa production, availability of social amenities, and welfare structures in the eight cocoa-producing communities. The questionnaires were tailored to different respondent categories, including community leaders, farmers, teachers, and children, to ensure relevance and clarity. Data collection was conducted over a defined period with trained enumerators administering the questionnaires to ensure accuracy and consistency.

Measurement of Variables

This study measured both the dependent and independent variables:

- **Dependent Variable**: The Protective Community Index (PCI) was the dependent variable. It was measured using the tool developed by the International Cocoa Initiative (ICI). PCI measures community resilience based on factors such as access to quality education, healthcare, and other protective structures.
- **Independent Variables**: These included socioeconomic characteristics such as age, gender, ethnic group, marital status, family structure, household size, farm size, level of education, reasons for children's involvement in cocoa production activities, and the availability of social amenities and welfare structures within the communities.

Data Analysis

The collected data were analyzed using descriptive and inferential statistical techniques. Descriptive statistics, including frequency distributions, percentages, and means, were used to summarize respondents' socioeconomic characteristics and community features. Inferential statistics, specifically Pearson product-moment correlation, were employed to test the hypotheses and determine the relationships between variables. The significance level was set at $P < 0.05$.

Results

Socioeconomic Characteristics of Respondents

The demographic characteristics of the respondents provided valuable insights into the social structure of cocoa-producing communities in the Idanre Local Government Area. Figure 1 highlights the respondents' age categories. This reveals that leadership roles were exclusively held by men aged 57-82 years, reflecting a traditional reliance on experience and seniority in community governance. Among the cocoa farmers, 50.4% were aged 44-56 years, while only 1% were between 18-30 years, underscoring a critical gap in youth participation. On the other hand, teachers were younger, with 70.8% aged 18-43 years, likely due to the profession's formal training requirements and appeal to younger demographics.

The sex distribution in Figure 2 highlights significant disparities. Leadership and farming were dominated by men (100% of community leaders and 91.8% of cocoa farmers), whereas teaching was predominantly female (73.2%).

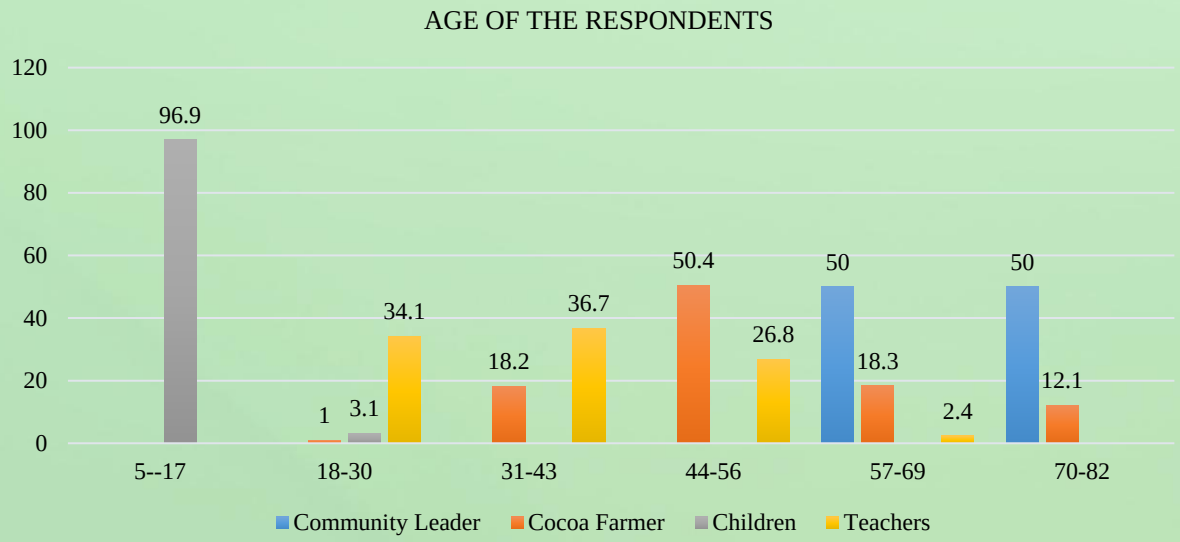


Figure 1. Frequency Distribution of the Age of the Respondents; Source: Field Survey, 2024

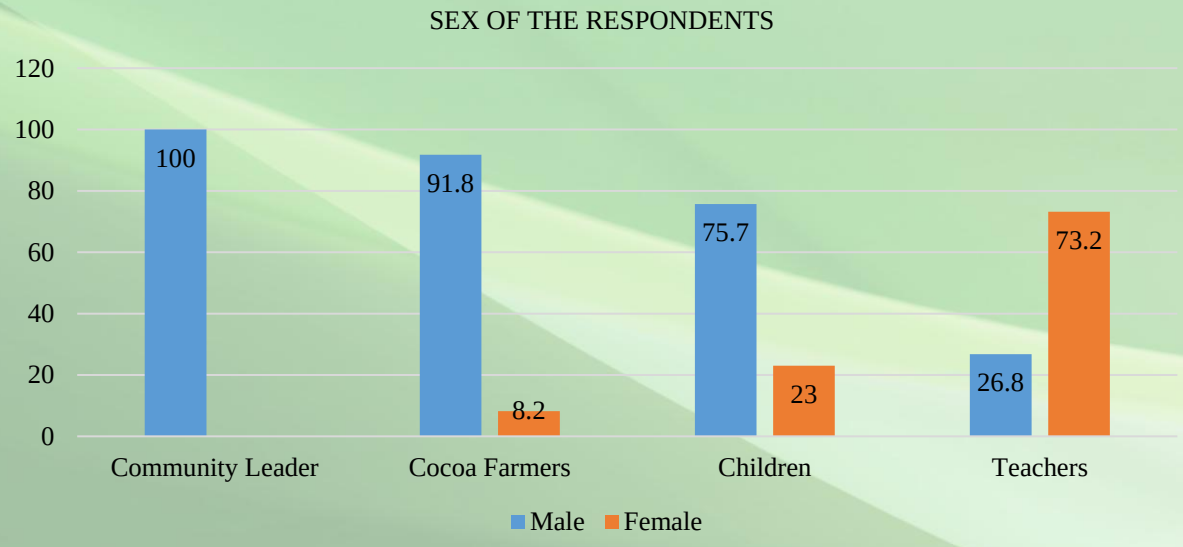


Figure 2. Frequency Distribution of the Sex of the Respondents; Source: Field Survey, 2024

The Level of Involvement of Children in Cocoa Production Activities

Table 1 shows that the level of involvement of children in cocoa production activities was minimal but notable, with 17.6% of the children engaging in cocoa production activities. The major activities include fetching water (mean = 2.11), the removal of cocoa beans (mean = 2.26), and turning fermented cocoa beans during the sun-drying process (mean = 2.36). Boys were more involved than girls, accounting for 75.7% of participants in cocoa production activities. The mean involvement score was 16.74 out of 50, indicating that most of the children's contributions were supplementary rather than central to farm operations.

Availability of Social Amenities and Welfare Structures in the Communities

Table 2 indicates that the availability of social amenities was inadequate, which was a significant challenge for the communities. Access to clean water was limited, with only 40% of respondents reporting reliable sources. Healthcare center facilities and services were similarly inadequate, with just 35% of communities having consistent access. Preschool availability was reported in 87.5% of the communities, and 75% had primary schools. Awareness programs addressing child labor were conducted in 75% of the communities, but no structured initiatives specifically targeting child labor reduction were available.

Availability of Supporting Structures for Children Welfare in the Communities

Table 3 shows that the welfare structures supporting children, such as scholarships (20%) and feeding initiatives or programs (15%), were scarce, reflecting systemic underinvestment in child welfare infrastructure. Only 41.5% of schools had separate restrooms for boys and girls, while none of the schools provided food for students. Additionally, scholarships for secondary education were available in only 14.6% of schools, and 9.8% of schools still employed corporal punishment as a disciplinary method.

Protective Community Index

The Protective Community Index (PCI) of the eight communities was moderate with an average score of 57.6%. This indicates that there is room for improvement in child protection and community resilience.

Hypothesis

H_{o1}: There is no significant relationship between the child's involvement in cocoa production and the Protective Community Index (PCI) of the study area.

The Relationship between Child Involvement in Cocoa Production and the PCI of the Study Area

Table 4 shows the results of the Pearson Product Moment Correlation (PPMC) analysis conducted to test this hypothesis. The results indicate that there is no significant relationship between the Protective Community Index (PCI) and child involvement in cocoa production activities (r = 0.06, p-value = 0.64).

Table 1. The Level of Involvement of Children in Cocoa Production Activities

Cocoa Production Activities	1 - 3 Hours F (%)	4 – 6 Hours F (%)	7 - 9 Hours F (%)	Mean
Nursery	45 (60.8)	9 (12.2)	1 (1.4)	1.94
Land/Farm Clearing	29 (39.2)	9 (12.2)		2.91
Transplanting	24 (32.4)	2 (2.7)		2.88
Fetching of Water	50 (67.6)	13 (17.6)	1 (1.4)	2.36
Spraying	8 (10.8)		2 (2.8)	1.71
Weeding	49 (66.2)	6 (8.1)		1.98
Pruning	11 (14.9)	4 (5.4)	1 (1.4)	1.86
Harvesting	13 (17.6)	9 (12.2)	3 (4.1)	2
Breaking of Pods	28 (37.8)	7 (9.5)	1 (1.4)	1.80
Removal of Cocoa Beans	24 (32.4)	34 (45.9)	7 (9.5)	2.36
Transport of Wet Cocoa Beans to the Fermentation Unit	8 (10.8)	1 (1.4)		1.77
Transport of Fermented Cocoa Beans to the Sun-Drying Unit	11 (14.9)		1 (1.4)	1.92
Turning the Fermented Cocoa Beans During the Sun-Drying Process	30 (40.5)	26 (35.1)	5 (6.9)	2.36
Transport of Dried Cocoa Beans to the Store	5 (6.8)			1.86
Transport/Carry Sack of Dried Cocoa Seeds from the Store into Dispatched Truck/Lorry	1 (1.4)			1.54

Source: Field Survey, 2024

Table 2. Availability of Social Amenities/Infrastructures in the Communities

Availability of Social Amenities/Infrastructures	Frequency	Percentage
Source of Clean Water		
River	2	25.0
Borehole	6	75.0
Healthcare Center		
Community Health Center	6	75.0
State Hospital	2	12.5
Community Households Hire Children for Cocoa Producing Activities		
Yes	1	12.5
No	7	87.5
Community Households Hire Adult Labourers for Cocoa Producing Activities		
Yes		
No	8	100
Awareness of Child Labor		
Yes	6	75.0
No	2	25.0
Availability of Pre-school in the Communities		
Yes	7	87.5
No	1	12.5
Availability of Primary Schools in the Communities		
Yes	6	75,0
No	2	25.0
Availability of Scholarships for the Children's Education		
Yes		
No	8	100
Availability of Community-Based Initiatives Addressing Child Labor		
Yes		
No	8	100

Source: Field Survey, 2024

Table 3. Availability of Supporting Structures for Children Welfare in the Communities

Availability of Supporting Structures for Children Welfare	Frequency	Percentage
Availability of restrooms in the primary school(s)		
Yes	16	41.5
No	24	58.5
Provision of Food in the primary school(s)		
Yes		
No	40	100
Availability of scholarships to attend high school		
Yes	5	14.6
No	35	85.4
Corporal punishment in primary schools		
Yes	4	9.8
No	37	90.2
School Regular Attendance		
Yes	34	85.4
No	6	14.6
School Absent Attendance in A Month		
1 day	4	9.8
2 days	19	48.8
3 days	11	26.8
4 days	3	7.3
5 days	3	7.3
School Absent Attendance in A Term		
2 weeks	22	56.1
3 weeks	14	34.1
4 weeks	3	7.3
10 weeks	1	2.4

Source: Field Survey, 2024

Table 4. Result of Pearson Products Moment Correlation between Child Involvement in Cocoa Production Activities and the PCI of the Study Area

Variable	r-value	p-value	Decision
Involvement Level vs. PCI	0.06	0.64	Not Significant

Source: Field Survey, 2024

Discussion

The gender imbalance in farming and leadership highlights persistent cultural norms that restrict women's participation in these roles, potentially limiting the inclusion of diverse perspectives in community decision making. The findings of this study provide critical insights into the dynamics (social and cultural norms) of cocoa-producing communities in the Idanre Local Government Area. The dominance of older men in leadership and farming roles aligns with traditional expectations of authority and physical labor. However, the low participation of youth in cocoa farming presents a critical challenge to the sustainability of cocoa production in Idanre. Young people's preference for urban employment opportunities underscores the need for policies that make agriculture more appealing through training, mechanization, and financial incentives. The low participation of adults in cocoa farming aligns with previous research highlighting youth migration to urban areas in search of alternative livelihoods (Amankwah et al. 2019).

Child labor in the study area, although limited and not widespread, remains a pressing concern. The fetching water activity involves providing water for various cocoa production processes or activities. It is straightforward and manageable for children, yet it demands physical effort and time that could otherwise be allocated to education. The removal of cocoa beans activity involves extracting beans from cocoa pods, an activity that requires handy work but not with physical strength, making it suitable for children. Although non-hazardous, excessive involvement could impact their school attendance. The turning of fermented cocoa beans activity is crucial in ensuring even drying during the sun-drying process. It is repetitive but not physically taxing, making it accessible for children. These activities are relatively simple and do not pose significant hazards to children. While these activities are non-hazardous, their implications for child labor must not be overlooked. Children's participation often aligns with household economic pressures, contributing to a school absenteeism rate of 5.4%. Although the activities are supplementary and do not directly endanger children, their involvement can disrupt educational continuity and overall development. The mean involvement score of 16.74 and 5.4% school absenteeism rate emphasize the need for targeted interventions to address the root causes of child labor, such as poverty and inadequate access to education. These findings suggest that economic pressures compel families to involve children in farm activities, although in a limited capacity. Gender disparities in child labor, with boys being more engaged, mirror the broader cultural expectations that assign physically demanding tasks to male children. Addressing these disparities requires community-specific strategies that balance economic needs with children's right to education and development. This finding shows the need for programs that address household economic needs while emphasizing the importance of education are critical. Awareness campaigns and community-based interventions can ensure children's involvement in cocoa production remains minimal and non-disruptive to their education in school and well-being.

Inadequacy of social amenities and welfare structures is a critical issue. The implications of these findings are significant. Limited access to clean water increases the risk of waterborne diseases, potentially leading to poor health outcomes and reduced school attendance. Inadequate healthcare facilities mean that illnesses are often untreated, make absenteeism worse and lower productivity. The absence of scholarships restricts educational advancement, causing economic hardship and the reliance on child labor. Furthermore, the lack of dedicated community initiatives to combat child labor leaves children vulnerable to exploitation, despite some level of awareness. Improving the availability and quality of these amenities is critical to enhancing the well-being of children and their communities. Investments in infrastructure, education, and health programs are essential for breaking the cycle of poverty and promoting sustainable development. These findings are consistent with studies that highlight the role of social infrastructure in mitigating child labor and promoting community development (ILO, 2020; UNICEF, 2023). The lack of separate restrooms particularly affects girls' school attendance and hygiene, while the absence of school feeding programs makes absenteeism worse and reduces the time children spend on education. Limited access to scholarships further restricts opportunities for higher education, perpetuating poverty and child labor. Although most schools do not practice corporal punishment, its presence in a few community schools shows the need for broader awareness and adoption of child-friendly disciplinary methods.

These deficiencies highlight the vulnerability of these communities to socioeconomic shocks and their limited capacity to support child protection. Addressing these deficiencies requires a holistic approach that includes investment in school infrastructure, the introduction of feeding programs, and expanded access to scholarships. Such interventions can enhance attendance rates, support children's well-being, and reduce their vulnerability to child labor, fostering a more protective environment within cocoa-producing communities.

A moderate PCI score of 57.6% indicated both progress and gaps in child protection within these communities. That is there are moderate protective measures, but significant improvements are needed. Investments in education, child welfare, and infrastructure are crucial to strengthening community resilience and reducing child labor. Expanding access to scholarships and feeding programs, improving healthcare, and implementing targeted interventions can create a more protective environment for children in cocoa-producing communities.

The lack of correlation highlights the possibility that other underlying factors, such as poverty, cultural norms, and economic dependency, play a more dominant role in driving child labor. These findings align with existing literature, which emphasizes that while community initiatives are valuable, they often fail to address deeper structural issues such as income inequality and inadequate access to education. This suggests that community-level protective measures, such as awareness campaigns or local initiatives designed to reduce child labor, may not directly influence the degree of children's participation in cocoa farming. Effective interventions should extend beyond community-level protective measures to include comprehensive strategies targeting economic reforms, educational support, and stronger enforcement of child labor policies. Such an integrated approach can help mitigate the socioeconomic and cultural factors contributing to child labor in cocoa-producing communities. Thus, enhancing social amenities, promoting gender equality, and supporting educational initiatives are essential for creating a more protective environment for children.

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Determination of the chemical composition of essential oil obtained from Cymbopogon citratus (DC.) Stapf leaves grown in Turkiye

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Abstract

Cymbopogon citratus (DC.) Stapf is an aromatic plant in the Poaceae family, known as lemongrass. *C. citratus* is widely grows naturally in India, Africa, South America, Indonesia, countries. It is used to make cosmetics and perfumes in the pharmaceutical industries, and as a culinary flavouring in the food industry. Leaves, aerial, roots of *C. citratus* has been used as cosmetics and perfumes, antipyretic, analgesic, spasmodic, diuretic, calming in Traditional Chinese Medicine. Essential oils of *C. citratus* comprises many chemical constituents such as citral mycrene, genariol, citronellol (cymbopogonol and cymbopogone) and α-oxobisabolene. It consist a significant group of essential oil, phenolic compounds, flavonoids, and other phytochemicals that have pharmacological activities such as antibacterial, antifungal, anticancer, antioxidant, antinociceptive, antiobesity, antidiarrhoeal and anti-inflammatory properties that can improve health. In this study, the chemical composition of the essential oil obtained from the leaves of *C. citratus* was analyzed by GC-MS. The essential oil analysis of *C. citratus* revealed a composition dominated by four major compounds: Geraniol acetate, Citral, β-Citral, and geranial.

Key Words: Cymbopogon citratus, essential oil, GC MS

Türkiye'de yetiştirilen Cymbopogon citratus (DC.) Stapf yapraklarından elde edilen uçucu yağın GC MS ile kimyasal bileşiminin belirlenmesi

Özet

Cymbopogon citratus (DC.) Stapf, limon otu olarak bilinen Poaceae familyasından aromatik bir bitkidir. *C. citratus* yaygın olarak Hindistan, Afrika, Güney Amerika, Endonezya, ülkelerinde doğal olarak yetişir. İlaç endüstrisinde kozmetik ve parfüm yapımında, gıda endüstrisinde ise mutfak aroması olarak kullanılır. *C. citratus*'un yaprakları, havası, kökleri kozmetik ve parfüm olarak, Geleneksel Çin Tıbbında ateş düşürücü, analjezik, spazmodik, idrar söktürücü, sakinleştirici olarak kullanılmıştır. *C. citratus* uçucu yağları sitral mikren, genariol, sitronellol (cymbopogonol ve cymbopogone) ve α-oksobisabolen gibi birçok kimyasal bileşen içerir. Sağlığı iyileştirebilen antibakteriyel, antifungal, antikanser, antioksidan, antinosiseptif, antiobezite, antidiyareik ve antiinflamatuar özellikler gibi farmakolojik aktivitelere sahip önemli bir uçucu yağ, fenolik bileşikler, flavonoidler ve diğer fitokimyasallar grubundan oluşur. Bu çalışmada, *C. citratus*'un yapraklarından elde edilen uçucu yağın kimyasal bileşimi GC-MS ile analiz edilmiştir. *C. citratus*'un uçucu yağ analizi, dört ana bileşiğin hakim olduğu bir kompozisyon ortaya koymuştur: Geraniol asetat, Sitral, β-Sitral ve geranial.

Anahtar Kelimeler: Cymbopogon citratus, uçucu yağ, GC MS

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Perceived Impact Of Tea Farming On Livelihoods Of Smallholder Farmers In Panchagarh District

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Abstract

The main objective of the study was to assess the perceived impact of tea farming on livelihoods of the smallholder tea growers. The research was conducted in the Tetulia upazila under Panchagarh district. A total of 550 farmers constituted the population of the study, and 118 small tea growers were selected as samples of the study following simple random sampling techniques. An interview schedule was used for data collection, and data was collected from 28 August to 12 October 2023. Perceived impact on livelihood of the small tea growers were assessed based on a five-point Likert scale. In contrast, both Pearson's product-moment correlation coefficient (r) and multiple linear regressions were performed to determine the relationships, influence and contribution of the selected characteristics to perceived impact of tea farming on livelihood of smallholder farmers. Present status explored that bought leaf factories are the major buyer of leaves and small-scale farmers were not getting the desired price of their tea leaves. The price fluctuation has happened over time in recent years and 20 to 40 percent deduction of the weight by the factories due to the long and large leaves. More than four-fifths of the tea growers cut raw leaves with a sharp knife instead of plucking leaves by hand. Most tea growers use pickup trucks to transport an excessive amount of raw leaves due to the high cost of labor and transportation which also degrades the quality of the tea. So, a significant proportion of the small tea growers who rely solely on income from tea farming opined that it is not profitable. Therefore, an overwhelming majority of tea growers are moderately satisfied by cultivating tea. Farmers have lost interest in cultivating tea due to the determining the price of raw leaves as desired by the factory owners and giving deductions on the leaves supplied by farmers and non-availability of low-cost agricultural credit and subsidized fertilizers and pesticides among small tea farmers. The bought leaf factories owners opined that unplanned tea farming by small growers supplied low quality and irregular raw leaves, impeding the production of good quality tea and causing a decline in tea auction market prices. The results of the study showed that tea farming had a medium perceived impact on livelihood of the 67.8 percent farmers. The selected characteristics of the farmers such as education status, farm size, tea cultivating area, income from tea farming, innovativeness, knowledge on tea farming, and attitude towards selling price of tea leaves have significant and positive effect on perceived impact of tea farming on livelihood of the small holder tea growers. Multiple regression analysis revealed that the whole model explained 63.9 percent of the total variation in the perceived impact of tea farming on livelihood of the small holder tea growers. Education status, innovativeness, knowledge on tea farming, and attitude towards selling price of tea leaves showed significant positive contributions to the perceived impact of tea farming.

Key Words: *Livelihood, Smallholder tea growers, Percieved impact, Tea farmers, Panchagarh district*

Introduction

The evergreen Camellia sinensis plant, a member of the Theaceae family, yields the leaves used to create the beloved beverage, tea (Arancon et al., 2007). Tea, the world's second most consumed beverage after water which is produced by the infusion of Camellia sinensis leaves. The world's total tea production is reported to increase from 2.9 million tons in 1994 to 6.1 million metric tons in 2019 (Ismail et al., 2020). The annual consumption of tea is assessed to be almost 273 billion liters and is anticipated to rise to 297 billion liters by 2021 (Ismail et al. 2020). Globally tea is one of the economic factors for many countries due to its large-scale plantation, production, marketing, and consumption (Hajiboland, 2017). It is the third commodity after petroleum and edible oil on which our billions of expenditures have been spent annually. It is a labor-intensive crop and produces employment and income generating possibilities and indirectly participates in economic development (Rehman et al., 2012). The main tea producing countries are China, India, Kenya, Sri Lanka, Vietnam, Argentina, and Turkey. In Bangladesh, tea stands as a significant cash crop and exportable commodity. The country's tea legacy dates back to 1840, with

the establishment of the first tea garden in Chittagong. Presently, tea cultivation flourishes in three ecologically diverse regions: the Surma valley in greater Sylhet, the Halda valley in Chittagong, and the Karatoa valley in Panchagarh. Bangladesh boasts 162 tea estates, spanning roughly 60,179 hectares of tea plantation, producing about 67.38 million kilograms of finished tea annually, with an average yield of approximately 1270 kilograms per hectare. Impressively, the tea industry contributes 0.11 percent to the nation's GDP (Raliman et al. 2020; Ahmad and Hossain 2013).

The Bangladesh Tea Research Institute (BTRI) has played a pivotal role in this success, introducing high-yield and quality clones along with hybrid seed stocks of biclonal and polyclonal origin (Alam, 2002). Various improvements, from revised fertilizer policies for mature and immature tea to optimized integrated pest control methods, have further enhanced tea production. The COVID-19 pandemic has not deterred the growth of tea production, particularly in Panchagarh and northern districts. The favorable climate and soil conditions in Panchagarh spurred its transformation into a key tea cultivation area in the late 1990s, with a significant increase in production. In 2020, Panchagarh alone produced over 10.30 million kilograms of tea, worth Tk 175 crore, marking a 7.11 lakh kg increase from the previous year (Daily Star, 2021).

This growth has not only met domestic demand but also expanded to international markets. The economic transformation has driven many farmers to switch from traditional crops to tea cultivation, fostering the emergence of 6,523 tea producers on 8,642 acres of land. Panchagarh is now home to 1,007 registered tea farmers and 10 large-scale tea estates, solidifying its status as a thriving tea cultivation hub (Dhaka Tribune 2021; Business Post 2022). Recently, primary producers have taken a significant financial hit as a result of the drop in price of raw tea leaf in the Tetulia Upazila of Panchagarh. However, tea farmers are not obtaining a fair price while the season is in progress. Despite the fact that there are vast gardens full of tea leaf, the price is quite low. Tea farmers are losing money because they are not receiving a fair price for their product. The owners of locally produced tea manufacturers were said to be members of a syndicate that was operating behind the tea price drop, according to allegations made by marginal producers. Over the course of the past few years, growers have been responding to market pressure to drive up tea leaf prices. In addition to that, they repeatedly formed chains of people. However, it failed to arouse any feeling of authority. Suddenly, the proprietors of tea factories have begun repressing their employees in the same manner as the Neelkars. The price of a kilogram of tea leaves has dropped to 11 taka. However, factories often subtract between 15 and 20 percent. This amount does not even come close to covering pay, much alone the cost of pesticides. The cost of producing one kilogram of tea leaves is around fourteen taka that is why farmers have to account for waste (Daily Star, 2022). It is of utmost need to research the linkages between socio-economic condition of smallholder tea growers, their tea farming status, and their livelihood condition. However, the purpose of this study is to provide answers of the following research questions:

i. What are the selected characteristics of the smallholder tea farmers?
ii. Is there any impact of tea farming on improving the livelihood status of smallholder farmers?
iii. What are the influences of farmers' selected characteristics on the perceived impact of tea farming on livelihood of smallholder farmers?

The promotion of tea cultivation as a nonconventional kind of agriculture is giving farmers rich returns in addition to offering enormous work opportunities, which is elevating the quality of life for thousands of people in five northern districts. Tea planting on plain lands is quickly developing in the "Kartoa Valley" ecological zone, which consists of five northern districts, according to the data of the Bangladesh Tea Board (BTB) at its Panchagarh Regional Office. This is transforming the rural economy. "Over 30,000 individuals, the most of whom are women are leading better lives in the Panchagarh, Thakurgaon, Dinajpur, Nilphamari, and Lalmonirhat districts of the valley." he stated. "These people are receiving higher salaries from farm-activities and picking tea leaves." The "Karton Valley" had an all-time record output of 14.54 million as of processed tea in 2021 as a consequence of increased tea growing This was an increase of 424 million kgs over the previous year's production of 10.30 million kgs of processed tea in the year 2020. According to Bangladesh Tea Board (BTB) authority, "Owners of nine registered and 21 unregistered tea estates and 8.067 smallholders planted tea on 11.434 acres of land in 2021." which is an increase of 1,264 acres compared to the 10.170 acres of land used for tea cultivation in 2020. When compared to the production of 51.28 million kgs of green tea leaves in the valley in 2020, the mountain region's output of green tea leaves increased to 73.57 million kgs in 2021 as a result of successful tea cultivation (Dhaka Tribune, 2021). Twenty-two businesses located in Panchagarh. Thakurgaon, and Lalmonirhat were responsible for the processing of 73.57 million kilograms (kg) of green tea leaves, which resulted in the production of 14.54 million kilograms (kg) of processed tea. This amount represented 15 percent of the total national production of 96.506 million kilograms (kg) in 2021 (Business Post, 2022).

The present study addresses the following specific objectives to:

i. determine and describe the selected characteristics of the smallholder tea growers;
ii. assess the perceived impact of tea farming on livelihoods of the smallholder tea growers; and
iii. explore the influence of the selected characteristics of the tea farmers on the perceived impact of tea farming on livelihood of smallholder farmers.

Materials and Methods

Study area

The study was conducted in northern Bangladesh, especially Tetulia Upazila under Panchagarh district of Bangladesh. Tetulia has an area of 189.12 square kilometers and is located between latitudes 26°24' and 26°38' north and longitudes between 88°21' and 88°33' east. This upazila is bounded on the north, south, and west by West Bengal, India, and on the east by Panchagarh Sadar upazila.

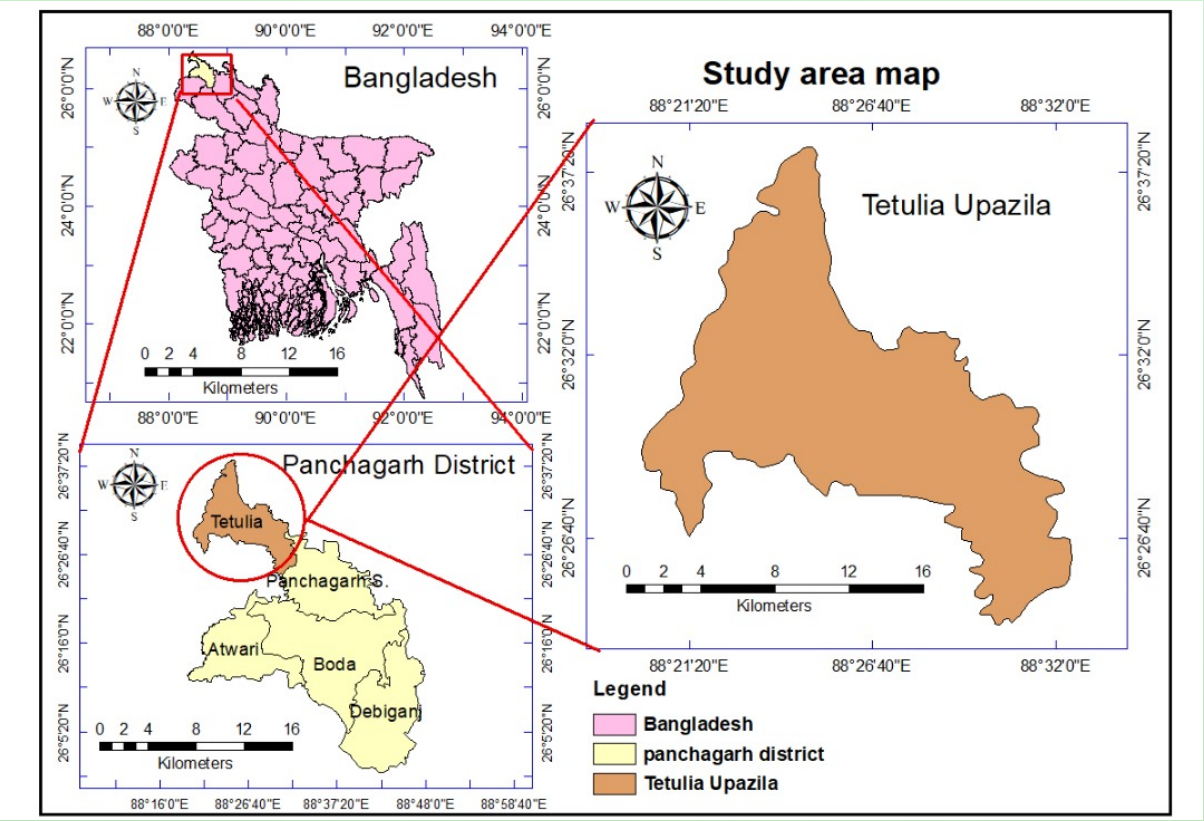


Figure 1. Map of Bangladesh and Panchagarh district showing the study area

Population and Sample

A total 550 small tea growers list was collected from Bangladesh Tea Board (BTB) Panchagarh Office, which constituted the population of this study. To make a respected sample from the population the following formula was used as developed by Kothari (2004).

$$n = \frac{Z^2PQN}{(N-1)\,e^2 + Z^2PQ}$$

Where,
n= Sample size
Z=the value of the standard normal variable at the chosen (95%) confidence level (1.96)
P= Probability assume (0.5)
Q= Remaining from probability (1-P)
N= Total population
e= the level of precision (8%)
By using this formula, 118 smallholder tea growers were selected as a sample of the study by following random sampling technique from the study area. Beside this, a reserved list of 20 farmers was prepared who were supposed to be interviewed only when a respondent in the original sample list was unavailable during data collection.

Research instrument and data collection

In order to collect valid and reliable information an interview schedule was prepared using both open and closed forms of questions to collect information. Simple, direct questions, statements and scales were included in the schedule to obtain information for independent and dependent variables. For Validity of the instrument pre-tested

with 20 respondents. Prior to completing the interview schedule, required adjustments and amendments were made based on the pre-test. The interviews were individually conducted at their respective residences and tea field of the respondents from 28 Aguest to 12 October 2023.

Variables of the Study

Measurement of independent variables

The independent variables of the study were focused on the smallholder tea farmers` socio-demographic profile of the smallholder tea growers and status of tea farming. The variables were as follows:

1. Age
2. Education status
3. Tea farming experience
4. Farm size
5. Recent tea cultivating area
6. Income from tea farming
7. Innovativeness
8. Extension contact
9. Knowledge on tea farming
10. Attitude towards selling price of tea leaves

Measurement of dependent variable

The dependent variable of this study was respondents` perceived the impact of tea farming on the livelihood of the smallholder tea growers. The variable was measured using a Likert scale (Likert 1932). The respondent was asked to express his/her opinion on 12 statements concerning tea farming, which were collected based on a review of the literature. The perceived impact of tea farming was measured by analyzing the perception index score. The ratings of the responses given by the respondents was measured following a 5-point Likert scale such as strongly agree, agree, no opinion, disagree, and strongly disagree, and the corresponding score of 5,4,3,2, and 1 was given for each of response, respectively. Thus, the Perceived impact of tea farming on livelihoods of Smallholder farmers could range from 0 to 60; while 0 indicating no Perceived impact of tea farming changed the livelihoods of Smallholder farmers and 60 indicating high perceived impact of tea farming the livelihoods of Smallholder farmers.

Data analysis

Different descriptive statistics like frequency, percentage, mean, standard deviation, and inferential statistics such as correlation, multiple linear regression, were employed. The Statistical Packages for the Social Sciences (SPSS) (version 25) was used to analyse the data. Results were presented in tables and graphs For clarity of understanding.

Results and Discussion

Characteristics profile of the smallholder tea farmers

The selected characteristics of smallholder tea growers included their age, education status, tea farming experience, farm size, tea cultivating area, income from tea farming, innovativeness, knowledge on tea farming and attitude towards selling price of tea leaves were presented in the Table 1. The age of the respondents ranged from 20 to 71 years, average being 39.79 years with a standard deviation of 11.61. Highest proportion (43.2 percent) of the respondents found in the young aged category compared to 33.1 percent middle and 23.7 percent old aged category. From the findings of the study young and middle aged tea growers constituted the major part. Because young age people are more amenable to new technologies such as cultivation of tea in the pain land, innovative, energetic, and risk taker than older on. Existing studies emphasizing the role of youth in agricultural transformation and are more likely to adopt agricultural innovations (Mahama et al., 2024, Harizanova-Bartos et al., 2019). The educational score of the tea farmers ranged from 0.5 to 18 with an average of 8.89 and standard deviation of 3.88. Results indicated that the highest proportion (45.8 percent) of the respondents had secondary level of education compared to 23.7 percent of them having higher secondary education, 9.3 percent of them having above secondary level education, 12.7 percent having primary level education and only 8.5 percent of the tea farmers could sign only. Thus, the majority (69.50 percent) of the tea farmers had education ranging from secondary to higher secondary level. The findings indicate the literacy rate of the tea growers is higher than the national average literacy of 55.7 percent (BBS, 2018). It can be assumed that the educational qualification of the tea growers may be higher than their neighbors'. Educated farmers are more likely to adopt modern farming techniques and management strategies (Worku, 2019). Higher education levels are also associated with an increased likelihood of embracing precision agriculture and sustainable farming practices (Hermans et al., 2021).

Additionally, research suggests that tertiary education contributes significantly to improving agricultural efficiency, as educated farmers are better equipped to comprehend and implement new agricultural technologies (Andrianarison et al., 2021). This supports the assumption that the educational qualification of tea growers provides them with the necessary skills for effective tea farming. Studies have also shown that farmers with access to formal education are more open to adopting innovations, which can lead to higher yields and better economic outcomes (Verma, 2024).

Table 1. Selected characteristics of the smallholder farmers (N=118)

	Scoring method	Range Observed (Possible)	Categories	Respondents No.	Respondents %	Mean	SD
Age	No. of years	20-71 (Unknown)	Young aged (<35) Middle aged (36-50) Old aged (>50)	51 39 28	43.2 33.1 23.7	39.79	11.61
Education status	Schooling year	0.5-18.0 (Unknown)	Can sign only (0.5) Primary (1-5) Secondary (6-10) Higher secondary (11-12) Above higher secondary (>12)	10 15 54 28 11	8.5 12.7 45.8 23.7 9.3	8.89	3.88
Tea farming experience	No. of years	2-14 (Unknown)	Less experienced (up to 6) Medium experienced (7-11) Highly experienced (≥12)	25 71 22	21.2 60.2 18.6	8.56	2.68
Farm size	Hectare	0.13-2.21 (Unknown)	Marginal (0.02-0.2 ha.) Small (0.2-1 ha.) Medium (1-3 ha.)	2 71 45	1.7 60.2 38.1	0.89	0.53
Tea cultivating area	Hectare	0.2-2.0 (Unknown)	Small (0.2-1 ha.) Medium (1-3 ha.)	71 47	60.2 39.8	0.90	0.50
Income from tea farming	('000'Tk.)	20-750 (Unknown)	Low income (up to 78) Medium income (79-471) High income (>471)	24 75 19	20.3 63.6 16.1	274.37	196.61
Innovativeness	Score	0-30 (Unknown)	Less innovative (up to 11) Moderately innovative (12-22) Highly innovative (>22)	77 32 9	65.3 27.1 7.6	9.06	6.62
Knowledge of tea farming	Score	6-19 (0 to 20)	Poor knowledge (up to 11) Fair knowledge (12-17) Good knowledge (>17)	13 90 15	11.0 76.3 12.7	14.31	3.11
Attitude of tea farmers towards selling price of tea leaves	Score	6-19 (0 to 20)	Poor knowledge (up to 11) Fair knowledge (12-17) Good knowledge (>17)	13 90 15	11.0 76.3 12.7	14.31	3.11

SD= Standard deviation

Thus, the findings from this study align with broader agricultural research, indicating that a higher education level significantly influences farmers' ability to adopt advanced techniques and improve productivity (Baldock et al., 2022). Tea farmers with at least a secondary education level are well positioned to engage in team farming enterprises effectively and enhance their livelihoods. Tea farming experience of the respondents ranged from 2 to 14 years. The mean tea farming experience is 8.56 years with a standard deviation of 2.68 years. Analyzed data demonstrated in Table 1 indicate that the majority (60.2 percent) of tea farmers had medium experienced of tea farming while 21.2 percent had jointly less experienced and only 18.6 percent highly experienced of tea farming. It means that the majority (78.8%) of the tea farmers had farming experience of medium to high experience of tea farming. The farm size of the respondents in the study area ranged from 0.13 to 2.21 hectares. The mean of farm size was 0.89 hectares with a standard deviation of 0.53 hectares. Results showed that majority of the respondents (60.2 percent) had small farms while 38.1 percent had medium farm size, and only 1.7 percent was marginal. The findings revealed that almost all (98.3 percent) of the respondents had small to medium farm size. In the context of the study area the respondents had farm sizes of up to 3 hectares, which is not so much less than we think. However, there are no landless respondents found in the study area. Studies indicate that larger farm sizes are associated with higher yields and greater economic returns due to economies of scale (Gessesse & He, 2021). However, smallholder farmers can still achieve high productivity through efficient land use, modern agronomic practices, and cooperative farming models (Ateka et al., 2018).

Additionally, research suggests that farm size influences household poverty levels, with small farms often yielding lower incomes, thus necessitating supplementary income sources (Rotich et al., 2017). In Kenya, smallholder tea farmers with diversified crop production reported higher profitability compared to those solely dependent on tea farming (Kanyua et al., 2015). Furthermore, land tenure security and access to land certification have been identified as critical factors in improving farm productivity. Secure land tenure allows farmers to make long-term investments in their tea farms, thereby enhancing production efficiency (Gessesse & He, 2021). Policies that support smallholder land consolidation, credit access, and technical training can significantly contribute to the economic viability of tea farming (Munishi et al., 2017). Overall, the study's findings align with existing literature emphasizing the importance of efficient land management, innovative farming techniques, and supportive policies to enhance smallholder tea farming sustainability. The range of recent tea cultivation areas from 0.2 to 2.0 hectares, mean was 0.90 hectares and standard deviation of 0.50. majority of the respondents (60.2 percent) had small recent

tea cultivated areas and 39.8 percent had medium recent tea cultivated areas. It means that a significant portion of tea growers may face lower incomes and potentially reduced livelihood stability due to limited land for cultivation, while 39.8 percent with medium sized areas may have a comparatively more secure economic base. Research shows that increasing farm size can significantly enhance tea yield and economic stability (Gessesse & He, 2021). Farmers with smaller tea farms may benefit from land consolidation and cooperative farming models to improve efficiency and profitability (Munishi et al., 2017). Additionally, the adoption of organic tea cultivation has been shown to improve the economic viability of smallholder farmers by increasing market value and reducing input costs (Doanh et al., 2018). Supporting smallholder farmers with better market access, extension services, and sustainable farming methods can enhance productivity and long-term economic sustainability (Ateka et al., 2018). Income from tea farming is the total annual money generated from cultivating and selling tea leaves. Income of the respondents from tea farming ranged from Tk. 20,000 to Tk.750, 000 with the mean of Tk. 274,370 and standard deviation Tk. 196,610. Findings showns that 63.6 percent of the respondents belonged to the medium of income followed by 16.1 percent in high and 20.3 percent in low income group from tea farming. Thus, the overwhelming majority (83.9 percent) of tea farmers had low to medium income from tea farming. This suggests that the livelihoods of many tea growers are moderately impacted by their income from tea farming, which might not provide a high standard of living or economic security. Income disparities among tea farmers are influenced by farm size, farming practices, and access to markets. Studies indicate that farmers with diversified cash crop production tend to earn more than those who rely solely on tea farming (Kanyua et al., 2015). Additionally, research suggests that contract farming and sustainability certification can enhance income by providing stable prices and premium market opportunities (Nguyen, 2020). In Tanzania, studies have shown that smallholder tea farmers with access to credit, extension services, and cooperative structures experience improved income stability (Dogeje & Ngaruko, 2023). Furthermore, improving infrastructure and market linkages can significantly boost smallholder tea farmers' earnings and reduce poverty levels (Rotich et al., 2017). Overall, these findings suggest that while tea farming provides a primary source of income for smallholder farmers, additional support in the form of cooperative farming, credit access, and sustainable practices is necessary to enhance economic security and long term viability.

The innovativeness scores of the respondents ranged from 0 to 30 with average of 9.06 and standard deviation were 6.62. The computed data indicated that 65.3 percent of the respondents had less innovativeness compared with 27.1 percent had moderately, and only 7.6 percent had highly innovativeness. The findings of the study revealed that more than half (65.3 percent) of the respondents had less innovativeness on modern agricultural technology. This means that the majority of the tea farmers had less innovativeness towards the improved farming practices in terms of duration of practicing improved farming on tea production. Knowledge on tea farming of the tea farmers ranged from 6 to 19 against the possible range of 0 to 20. The mean and standard deviation were 14.31 and 3.11 respectively. It can be clearly seen from the findings that an overwhelming majority (76.3 percent) of the respondents possessed fair knowledge on tea production, followed by 11.0 percent with less and 12.7 percent having good level of knowledge of tea farming. Thus, we can conclude that 87.3 percent of the tea farmers had low to fair knowledge on tea farming and highlighting the potential need for educational and training programs in tea farming. When it comes to selling price of tea leaves, attitude defines how they approach the challenges and opportunities associated with the fluctuating prices of their tea leaves. Considering the drop of raw leaf, the attitude of the respondents was measured. Attitude scores of the respondents towards selling price of tea leaves could theoretically range from 0 to 100. However, their observed scores ranged from 30 to 81 with an average of 50.65, and standard deviation of 7.64. It was found that among the respondents' 50.0 percent belong to moderately favorable attitude category while 24.6 percent had moderately favorable attitude, 15.3 percent had highly favorable attitude, 8.5 percent had highly unfavorable attitude and only 1.7 percent had neutral attitude towards selling price of tea leaves. These findings suggest that most farmers are neither strongly optimistic nor completely dissatisfied with tea leaf prices but maintain a cautiously optimistic stance. Several factors contribute to this moderate satisfaction level. The fluctuation in raw tea leaf prices at different bought-leaf factories, potential collusion between buyers and sellers, and increasing costs of tea cultivation may all influence farmers' attitudes. Research has shown that tea smallholders often perceive pricing structures as unfair due to external control by factory owners and market intermediaries (Kakoty, 2021). Additionally, studies in Kenya have demonstrated that price volatility in the tea sector creates uncertainty for smallholder farmers, impacting their willingness to expand production and invest in quality improvement measures (Kiplimo et al., 2015). Moreover, tea pricing decisions are influenced by factors beyond the farmers' control, including agro-climatic conditions, plucking standards, and the cost of inputs (Kanyua et al., 2015). In the case of Bangladesh, farmers in Panchagarh have expressed disillusionment due to not receiving the expected fair prices for their tea leaves. The initial phase of tea farming was characterized by fewer cultivars and higher pricing, but as the number of tea farmers increased, the market became more competitive, leading to lower prices and reduced profit margins. This aligns with global trends, where increased supply often drives prices down, especially in commodity markets dominated by large processing units (Mahindapala, 2020).

To improve pricing satisfaction among tea smallholders, researchers suggest the adoption of collective marketing strategies, participation in cooperatives, and the establishment of price stabilization mechanisms (Trimo et al., 2018). Moreover, branding and certification of specialty tea can enhance the market value of tea leaves, enabling farmers to receive premium prices (Raj, 2021).

Extension contact

Extension contacts measure the level of interaction between tea farmers and tea extension workers, and it is a very effective and powerful source of receiving information about various new and modem technologies.

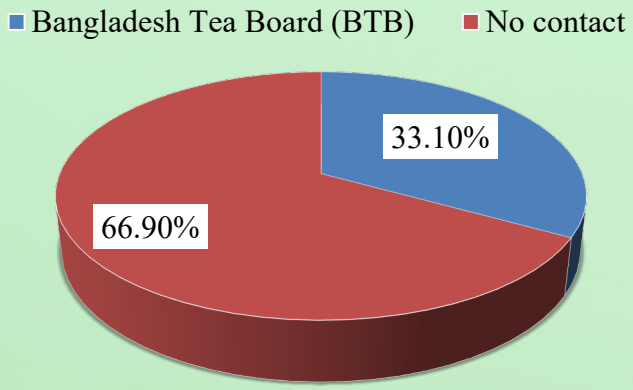


Figure 2. Distribution of the smallholder tea growers based on their extension contact

Graphical data in Figure 2 indicated that Majority (66.9 percent) of the tea farmers have no contact with extension compared to 33.1 percent of them having Bangladesh tea board (BTB) extension contact. It may be remarked that many tea farmers lack access to extension services, but those who access to extension contact like Bangladesh Tea Board (BTB) gain valuable insights into new agricultural technologies. This information can enhance their tea cultivation, leading to higher crop yields which can influence their livelihoods. Furthermore, studies in Sri Lanka have highlighted the importance of public-private partnership (PPP) extension models in bridging the gap between government-led and private-sector advisory services. These models have been shown to improve trust, technical knowledge sharing, and farmer participation in sustainable tea production (Amarathunga & Jayasinghe, 2024). Similarly, research on extension services in Indonesia has found that smallholder farmers who engage with agricultural extension programs tend to adopt better farm management strategies, leading to increased efficiency and income (Kosim et al., 2021).

Despite these benefits, challenges remain in ensuring widespread access to extension services. Research suggests that privatized extension models often face governance and accountability issues, which can limit their effectiveness for smallholder tea farmers (Mbeche et al., 2021). Thus, policymakers and agricultural agencies should focus on expanding extension outreach, improving farmer education programs, and integrating technology based advisory services to ensure that all smallholder tea growers can access essential agricultural information.

Perceived Impact of Tea Farming on Livelihoods of Smallholder Tea Growers

The perceived impact of tea farming on livelihoods of Smallholder tea growers was determined was assessed in three ways:

a) By assessing the overall perceived impact of tea farming on livelihood of smallholder tea growers, (b) by assessing dimension wise perceived impact of tea farming on livelihood of small tea growers, (c) by assessing the statement-wise perceived impact of tea farming.

The results are as follows:

Overall perceived impact of tea farming on livelihoods of smallholder tea growers

The observed overall perceived impact of tea farming scores ranged from 31 to 49 against the possible range of 12 to 60 with a mean of 39.75 and standard deviation of 4.62. Based on Their 'Perceived impact of tea' scores the respondents were classified into three categories such as 'Low perceived impact' (up to 35), 'Medium perceived impact' (36-45), and 'High perceived impact' (above 45) as shown in Table 2.

Table 2. Distribution of the smallholder tea growers based on their perceived impact on livelihood

Range		Categories (in score)	Frequency	Percent	Mean	SD
Possible	Observed					
12-60	31-49	Low perceived impact (up to 35)	24	20.3	39.75	4.62
		Medium perceived impact (36-45)	80	67.8		
		High perceived impact (above 45)	14	11.9		
		Total	118	100.0		

The results of Table 2 show that highest proportion (67.8 percent) of respondents believed that tea farming had a medium perceived impact on their livelihoods. A smaller proportion (20.3 percent) perceived a low perceived impact and while only 11.9 percent perceived a high perceived impact of Tea farming. This indicates that a very large majority (88.1 percent) of the respondents fell within the low to medium perceived impact category, suggesting that the overall perceived impact of tea farming on their livelihoods was not very high.

Dimension wise perceived impact on livelihood of small tea growers

To measure the perceived impact of tea farming on livelihoods, five dimensions of livelihood were considered, as shown in Figure 3. The ranking of perceived impact of tea farming on livelihoods based on their Perceived Impact Indices (PIIs) was presented through a graphical representation in the form of a spider diagram representing the five dimensions.

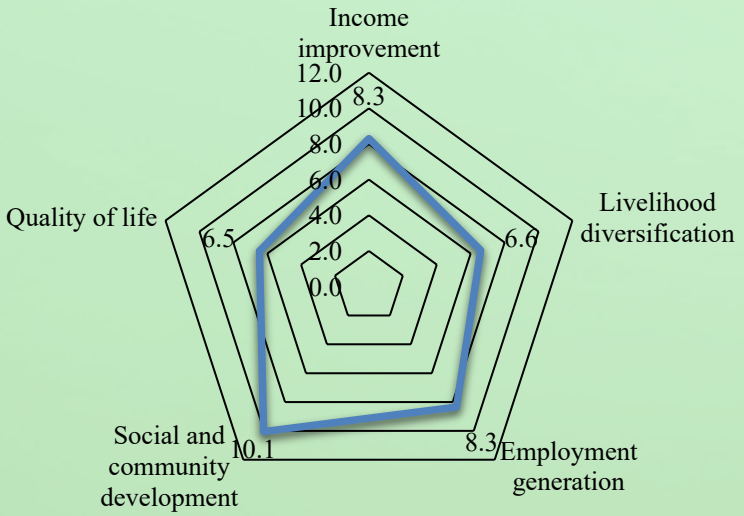


Figure 3. Dimension wise perceived impact on livelihood of small tea growers

Result of Figure 15 shows that among five dimensions of tea farmer's livelihood, Social and community development (PIIs=10.1) was mostly perceived impact by tea farming, followed by employment generation (PIIs=8.3) and income improvement (PIIs=8.3) were the second most. Livelihood diversification (PIIs=6.6) was the third and Quality life was the least perceived impact among all the five dimensions of tea farmer's livelihood.

Statement-wise perceived impact of tea farming

Twelve statements related to livelihoods of smallholder tea farmers were considered for measurement perceived impact of Tea farming. The ranking of the statements was done based on their Statement-wise Perceived Impact on Livelihood Index (PILI) and they are presented in Table 3. For having better understanding regarding perceived impact of Tea farming on livelihoods of Smallholder tea farmers, it was necessary to have an idea about the comparative statements in 12 selected statements. For this purpose, Statement-wise Perceived Impact on Livelihood Index (PILI) was computed.

The computed indices score of the 12 statements ranged from 288 to 521 against a possible range of 0 to 590. The rank order according to their Statement-wise Perceived Impact on Livelihood Index (PILI) is shown in Table 3.

Result in Table 11 indicate that 'tea farming has provided employment for local communities in the tea sector' (PILI=521) was the most perceived impact due to Tea farming. 'Tea farming has created job opportunities for me and other members of my household' (PILI=464) was found to have the second most perceived impact due to Tea farming. 'Tea farming has opened opportunities for additional livelihood activities' (PILI=424) emerged as the third most perceived impact due to Tea farming. 'Tea farming has significantly increased my household income' (PILI=288) was the least perceived impact due to Tea farming among the 12 selected statements.

Influencing variables to perceived impact of tea farming on livelihoods of smallholder farmers

Correlation Analysis

This section deals with the findings of the relationships between the selected characteristics of tea farmers and the perceived impact of tea farming on livelihood of smallholder farmers. The selected characteristics of the tea farmers are age, educational status, tea farming experience, farm size, tea cultivating area, income from tea farming, innovativeness, extension contact, knowledge on tea farming and attitude towards selling price of tea

leaves. The dependent variable was perceived impact of tea farming on livelihood of smallholder farmers. Pearson's Product Moment Correlation co-efficient (r) was used to determine the relationships between the selected characteristics of the farmers and the perceived impact of tea farming on the livelihood of smallholder farmers. At highest five percent (0.05) level of significance was used as the basis for rejection of a null hypothesis. The correlation analysis (Table 4) shows that eight out of ten variables are significantly positive related to the perceived impact of tea farming on the livelihood of smallholder farmers namely ,educational status, farm size, tea cultivating area, income from tea farming, innovativeness, extension contact, knowledge on tea farming and attitude towards selling price of tea leaves. In contrast, only age and tea farming experience had no significant relationship with the perceived impact of tea farming on the livelihood of smallholder farmers at five percent level of significance.

Table 3. Rank order of the livelihood options based on perceived impact on livelihood index value

Sl. No.	Statements	Level of agreement					*PILI	**RO
		SA	A	UD	DA	SDA		
(A) Income improvement:								
1.	Tea farming has significantly increased my household income	24	29	55	9	1	288	12th
2.	Tea farming has provided me with a stable source of income	1	24	65	28	0	356	9th
3.	Tea farming has helped me meet my financial needs and expenses	1	42	50	24	1	336	11th
(B) Livelihood diversification:								
4.	Tea farming has allowed me to diversify my income sources	18	20	30	44	6	354	10th
5.	Tea farming has opened up opportunities for additional livelihood activities	3	13	19	77	6	424	3rd
(C) Employment generation:								
6.	Tea farming has created job opportunities for me and other members of my household	0	16	5	68	29	464	2nd
7.	Tea farming has provided employment for local communities in the tea sector	0	0	8	53	57	521	1st
(D) Social and community development:								
8.	Tea farming has improved the social status and recognition of tea growers in the community	2	23	12	74	7	415	4th
9.	Tea farming has fostered a sense of community among tea growers	4	19	11	83	1	412	5th
10.	Tea farming has led to the development of social infrastructure and services in the area	15	23	24	54	2	359	8th
(E) Quality of life:								
11.	Tea farming has improved the living standards of small holder tea growers	4	38	26	45	5	363	7th
12.	Tea farming has provided better access to education, healthcare, and other essential services	9	22	31	49	7	377	6th

*Perceived Impact on Livelihood Index; **Rank Order

Table 4. Relationships between the dependent and independent variable

Dependent Variable	Independent variables	Calculated 'r' value at 116 df.	Tabulated 'r' value at 116 df.	
			0.05% Level	0.01% Level
Perceived impact of tea farming on livelihoods of smallholder farmers	Age (X_1)	0.157	±0.183	±0.239
	Education status (X_2)	0.317**		
	Tea farming experience (X_3)	0.113		
	Farm size (X_4)	0.200*		
	Tea cultivating area (X_5)	0.185*		
	Income from tea farming (X_6)	0.232*		
	Innovativeness (X_7)	0.701**		
	Extension Contact (X_8)	0.206*		
	Knowledge on tea farming (X_9)	0.524**		
	Attitude towards selling price of tea leaves (X_{10})	0.296**		

*Correlation is significant at the 0.05 level and ** Correlation is significant at the 0.01 level

Multiple linear regression analysis

Multiple regression analysis (enter methods) was run to determine the influence of explanatory variables on Perceived impact of tea farming on livelihoods of smallholder farmers. Out of ten independent variables, eight were included in multiple regression analysis due to their significant values in correlation analysis (Table 4). The coefficient of determination (R2) indicates that all the independent variables explain 66.3 percent of the variance in the perceived impact of tea farming on smallholder farmers' livelihoods. The adjusted R2, calculated by only including the significant independent variables, reveals that 63.9 percent of the dependent variable's variation is attributable to these independent variables. Of them only four variables namely education status, innovativeness, knowledge on tea farming and attitude towards selling price of tea leaves had positive significant contribution to the perceived impact of tea farming on the livelihood of smallholder farmers. The contributions of the remaining selected characteristics were insignificant.

Table 5. Contribution of selected characteristics to the perceived impact of tea farming on the livelihood of smallholder farmers

Selected characteristics of the respondents	Unstandardized Coefficients		Standardized Coefficients	% Contribution	*t*-value
	β	SD	β		
(Constant)	23.410	1.966			11.906
Education status (X_2)	0.137	0.071	0.115		1.930*
Farm size (X_4)	0.106	0.697	0.012		0.152
Tea cultivation area (X_5)	-0.364	0.712	-0.039		-0.512
Income from tea (X_6)	0.001	0.001	0.038	63.9	0.605
Innovativeness (X_7)	0.408	0.042	0.585		9.679**
Extension contact (X_8)	0.037	0.347	0.006		0.108
Knowledge on tea farming (X_9)	0.472	0.091	0.318		5.186**
Attitude towards selling price of tea leaves (X_{10})	0.091	0.036	0.151		2.537**

* Significant at 5% level of significance and ** Significant at 1% level of significance; R^2=0.663; Adjusted R^2=0.639; F change= 26.86; SD= Standard deviation

In this connection however, the researcher rejected the null hypothesis concerned and concluded that each of the factors had a significant effect on the perceived impact of tea farming on smallholder farmers' livelihoods. In other words, the extent of perceived impact of tea farming on livelihood by the smallholder tea growers was influenced by those four factors. Innovativeness has the strongest positive impact, showing that farmers who adopt new techniques, value addition, and modern farming practices perceive greater benefits. This aligns with studies highlighting that innovative farmers achieve higher productivity and profitability (Nyokabi et al., 2024). Similarly, knowledge on tea farming is another major contributor, as better informed farmers can optimize their farming practices, leading to improved yields and income (Maina et al., 2012).

The attitude towards selling price of tea leaves also plays a crucial role, indicating that farmers who view tea prices favorably perceive more benefits from tea farming. This suggests that market confidence and price stability enhance farmer satisfaction and investment in tea production. Additionally, education status significantly impacts perception, as educated farmers tend to make informed decisions, adopt improved practices, and access better markets, leading to enhanced livelihood benefits.

Conclusions

Based on the major findings of the study and their logical interpretation the following conclusions were drawn:

- The selected characteristics of the smallholder tea growers reveals that majority of the respondents were young to middle aged having eleven years of experience with small tea cultivation area and very poor extension contact with Bangladesh tea board officials. The small growers have fair knowledge but due to not receiving any training they were unable to use their knowledge which leads them less innovative practices in tea farming.
- Tea farming had a medium perceived impact on the livelihood of the small tea growers which is mostly impacted in social and community development compared to other four dimensions of livelihood because tea is cultivated commercially in this area by other different tea state and small tea garden producers. Therefore, it might be concluded that though their livelihood was not expectedly impacted by tea farming but impacted in other considered dimensions of livelihood.
- Both the correlation and regression analyses showed that education status, innovativeness, knowledge on tea farming, and attitude towards the selling price of tea leaves had significantly influenced the perceived impact of tea farming on the livelihoods of smallholder farmers. These factors positively contribute to the economic stability and overall well-being of the tea farmers. Specifically, innovativeness showed the strongest positive

relationship (r = 0.701**), while education, knowledge, and attitude towards the selling price of tea leaves also have substantial positive impacts. Conversely, age and tea farming experience do not significantly affect the perceived impact. The results underscore the importance of fostering education, promoting innovative practices, enhancing knowledge dissemination, and empowering farmers in market negotiations to improve their livelihoods.

Recommendations

Based on the above conclusions and experience of the present study the following recommendations were made:

Recommendations for policy implications

- The findings of the study indicated that an overwhelming majority (82.5 percent) of the respondents have not received any training in tea farming. Therefore, Bangladesh Tea Board (BTB) may establish institutional tea training center for enhancing the tea farmers' competence and provide low-cost agricultural credit with subsidized fertilizers and pesticides among small tea farmers.
- Working along with both the Bangladesh Tea Board (BTB) and the Department of Agricultural Extension (DAE) to diagnose crops and tea fields and choose commercial tea-growing places for better quality tea instead of scattered cultivation in homestead area.
- The ministry of commerce needs to realize and take necessary measures for capacity building of Panchagarh BTB office for providing better services to the tea producers. The Ministry of commerce also may provide more rural inclusive financing and widening alternative use of tea leaves for tea growers.

Recommendations for further study

A piece of study cannot provide all information for proper understanding of the perceived impact of tea farming on the livelihood of smallholder farmers. It was felt that much investigation is needed for clear understanding of the perceived impact of tea farming on livelihood of smallholder farmers. Hence, the following suggestion might be helpful for further research:

- The study was conducted on perceived impact of tea farming on livelihood of smallholder farmers in Tetulia upazila under Panchagarah district of northern Bangladesh. The findings of this study should be verified by similar research in other parts of the country.
- This study investigated the relationship of ten selected characteristics of the tea farmers with the perceived impact of tea farming on the livelihood of smallholder farmers. Therefore, further research could be conducted to assess the relationships of other characteristics of the smallholder tea farmers with the same.
- Age and tea farming experience of the tea growers had no relationship with their perceived impact of tea farming on livelihood of smallholder farmers. As a result, further verification is necessary in this regard.

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Phytogenic Feed Additives: Their Role in Animal Nutrition

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Abstract

Phytogenic feed additives are used to improve feed quality, support growth and improve animal health. These additives have antimicrobial, antioxidant and gut-flora-regulating properties. Phytogenic compounds offer a safe and economical alternative as feed additives. The use of these feed additives, which are safe and of high nutritional quality, is very important for optimum animal performance. With the decrease in the use of antibiotics, phytogenic feed additives are becoming more preferred. Plants such as thyme, mint and basil improve growth performance and feed conversion in poultry. Turmeric has antioxidant and anti-inflammatory properties. The appropriate dosage of phytogenic feed additives is still unclear. Differences in the conditions under which plants grow in different regions make this difficult. However, these additives are considered to be safe and environmentally friendly alternatives. Plants such as cinnamon, thyme and cloves improve digestion by increasing the palatability of the feed. Essential oils have a positive effect on the activity of digestive enzymes. Phytogenic feed additives improve weight gain and feed conversion in chickens. Garlic, thyme and cornflower supplements also show positive effects. As a result, phytogenic feed additives are becoming increasingly popular in the feed industry as they improve animal performance, the immune system and feed palatability. As natural compounds of plant origin, these substances offer safe and healthy alternatives.

Key Words: *Anti-microbial properties, antioxidant effects, phytogenic feed additives, medicinal plants, essential oils*

Fitojenik Yem Katkı Maddeleri: Hayvan Beslenmesindeki Rolü

Özet

Fitojenik yem katkı maddeleri, yem kalitesini iyileştirmek, büyümeyi desteklemek ve hayvan sağlığını iyileştirmek amacıyla kullanılmaktadır. Bu katkı maddeleri, anti-mikrobiyal, antioksidan ve bağırsak florasını düzenleyici özellikleri ile dikkat çekmektedir. Fitojenik bileşikler, yem katkı maddesi olarak güvenli ve ekonomik bir alternatif sunmaktadır. Güvenli ve yüksek besin kalitesine sahip olan bu yemlerin kullanımı hayvanların optimum performansı için oldukça önemlidir. Antibiyotik kullanımının azalmasıyla birlikte fitojenik yem katkı maddeleri daha fazla tercih edilmektedir. Kekik, nane, fesleğen gibi bitkiler, kümes hayvanlarının büyüme performansını ve yem dönüşüm oranını artırmaktadır. Zerdeçalın antioksidan ve anti-inflamatuar özellikleri bulunmaktadır. Fitojenik yem katkı maddelerinin uygun dozu konusunda hala netlik yoktur. Farklı bölgelerde yetişen bitkilerin koşulları arasındaki farklılıklar bu durumu zorlaştırmaktadır. Ancak, bu katkı maddeleri güvenli ve ekolojik dost alternatifler olarak değerlendirilmektedir. Tarçın, kekik ve karanfil gibi bitkiler, yemin lezzetini artırarak sindirimi iyileştirmektedir. Uçucu yağlar ise sindirim enzimleri aktivitelerini olumlu yönde etkilemektedir. Fitojenik yem katkı maddeleri, tavukların ağırlık kazanımı ve yem dönüşüm oranını iyileştirmektedir. Sarımsak, kekik ve peygamber çiçeği takviyeleri de olumlu etkiler göstermektedir. Sonuç olarak, fitojenik yem katkı maddeleri, hayvan performansını, bağışıklık sistemini ve yem lezzetini iyileştirerek yem endüstrisinde giderek daha popüler hale gelmektedir. Bu maddeler, bitkisel kaynaklı doğal bileşikler olarak güvenli ve sağlıklı alternatifler sunmaktadır.

Anahtar Kelimeler: *Anti-mikrobiyal özellik, antioksidan etki, fitojenik yem katkı maddeleri, tıbbi bitki, uçucu yağlar*

Giriş

Ganguly (2013), fitojenik yem katkı maddelerinin genellikle yem özelliklerini iyileştirmek, bireysel üretim performansını teşvik etmek ve bu hayvanlardan elde edilen gıdanın kalitesini artırmak amacıyla kullanıldığını bildirmiştir. Fitojenik bileşikler, kümes hayvanlarının beslenmesinde antimikrobiyal, antioksidan ve bağırsak florasını düzenleyici etkiler göstermektedir (Gürbüz ve ark., 2019). Bu da tıbbi bitkilerin yem katkı maddesi olarak kabul edilebileceğini göstermektedir.

Güvenli ve yüksek besin kalitesine sahip yemlerin ve katkı maddelerinin kullanımı, hayvanların optimum performansı için oldukça önemlidir (Omenka ve Anyasor, 2010). Ancak, hayvan yemlerinde kullanılan bazı yem katkı maddelerinin üretiminde yeni teknolojilerin kullanımı, gıda güvenliği üzerinde oluşturduğu zorluklar nedeniyle sorgulanmaktadır. Günümüzde, birçok ülkede kümes hayvancılığı endüstrisinde antibiyotik kullanımı azalmaktadır. Bu azalmanın nedenleri arasında, tüketicilerin tercihi (Adedoyin ve ark., 2017), bazı sentetik yem katkı maddelerinin hayvancılık ve tüketici sağlığı üzerindeki zararlı etkileri ve ticari premikslerin (Adegbenro, 2015) ve antimikrobiyal büyüme hızlandırıcıların (AGP'ler) yüksek maliyetleri yer almaktadır. Bu nedenle, ekonomik olması ve uygun şekilde uygulandığında insanlarda kalıntı etkisi bırakmaması nedeniyle kümes hayvanı diyetlerinde fitojenik yem katkı maddelerinin kullanımı teşvik edilmektedir.

Rasyonlara % 0.1-0.5 düzeyinde kekik eklenmesinin, yumurta tavuklarında yem dönüşüm oranında bir iyileşmeye neden olduğu gözlenmiştir (Banerjee ve ark., 2013; Al-Kalabi ve Al-Kassie, 2013). Nane ve fesleğen yaprakları, öjenol, sitronellol, linalool, sitral, limonen ve terpineol gibi sağlık açısından faydalı uçucu yağlar içeren çok sayıda bitki kaynaklı kimyasal bileşik içermektedir (Gürbüz ve Salih, 2017). Sumak ve zencefilin broiler diyetlerinde kullanıldığında performansı olumlu yönde etkilediği ortaya çıkmıştır (Abdelaziz, 2015; Gürbüz ve Salih, 2017). Bir başka çalışmada, fitojenik yem katkı maddelerinin piliçlere verilmesinin büyüme performansını artırdığı vurgulanmıştır (Gürbüz ve ark., 2019). Tarçın, kekik, mercanköşk, kırmızı biber ve turunçgil özlerinin broiler rasyonlarına eklenmesi ile hayvanların vücut ağırlıkları artmıştır (Lippens ve ark., 2005). Benzer sonuçlar, Mountzouris ve ark. (2011) tarafından kekik, anason ve turunçgillerde piliçler üzerinde gözlenmiştir.

Fitojenik yem katkı maddelerinin faydalı etkilerine rağmen, kümes hayvanı üretiminde kullanılacak uygun doz netlik kazanmamıştır. Dünyanın farklı yerlerinde bulunan bitkilerin yetiştirme koşulları arasındaki farklılıklar, bitkilerin hasat dönemleri ve kümes hayvanı diyetlerine fitojenik yem katkı maddelerinin dahil edilme seviyelerinin standartlaştırılmaması zorluk oluşturmaktadır. Ancak, fitojenik yem katkı maddeleri, güvenli ve ekolojik olarak dost olmaları nedeniyle, antimikrobiyal büyüme destekleyicilerine göre daha iyi bir alternatif olarak değerlendirilebilmektedir (Oladeji ve ark., 2019).

Nanenin antioksidatif aktiviteleri, kekik ve mercanköşkteki fenolik terpenler ile yüksek oranda monoterpen, timol ve karvakrolün varlığından kaynaklanmaktadır (Rahim ve ark., 2011). Sarımsak ve soğanın içindeki kükürt bileşenleri, hem lipid oksidasyonunu azaltmış hem de kümes hayvanlarında düşük yoğunluklu lipoproteinlerin oksidasyonunu engellemiştir (Ahmed ve Bassuony, 2009).

Fitojenik yem katkı maddeleri, patojenlere karşı antimikrobiyal etkileriyle bilinmektedir. Ayachi ve ark. (2009), kekiğin içerdiği timol ve karvakrol bileşenleri nedeniyle Salmonella ve Candida albicans gibi mantarlara karşı etkili olduğunu vurgulamıştır.

Zerdeçalın, antioksidan ve antienflamatuar özelliklerinin yanı sıra antitümöral aktiviteleri de bulunmaktadır. Alloui ve ark. (2014) göre, %1 zerdeçal baharatı ile yem takviyesi, Eimeria maxima ile enfekte tavuklarda kilo alımını iyileştirmiş, bağırsak lezyonlarını ve oosit atılımını azaltmıştır.

Bazı fitojenik yem katkı maddeleri, kümes hayvanları için yemin tadını, lezzetini ve kabul edilebilirliğini iyileştirerek performanslarını artırmaya yardımcı olmaktadır. Tarçın özü, kekik ve karanfil, safra, mukus ve tükürük sindirim salgılarını uyarmakta ve enzim aktivitelerinin iyileştirilmesine yardımcı olmaktadır (Platel ve Srinivasan, 2004). Ayrıca, bitkilerden elde edilen bazı yağlar, tavuklarda tripsin ve amilaz aktivitelerini olumlu yönde etkileyerek ve bağırsak mukusunda uyarıcı etkiler yaratarak mikroplardaki dengeyi korumaktadır (Jamroz ve ark., 2006).

Fitojenik yem katkı maddeleri, tavukların ağırlık kazanımı ve yem dönüşüm oranı açısından kümes hayvanlarının üretim performanslarında önemli bir iyileşme sağlamaktadır. Trigonella foenum-graecum takviyesi, broiler tavukların yem dönüşüm oranını önemli ölçüde iyileştirmiş olup, bu durum gastrointestinal dokulardaki morfolojik değişikliklerle ilişkilendirilmiştir (Mamoun ve ark., 2014).

Sarımsağın, yumurta üretimini artırdığı, serum ve yumurta sarısının kolesterol içeriğini azalttığı ve yumurtacı tavuklarda bağışıklık tepkisini iyileştirdiği belirlenmiştir (Azeke ve Ekpo, 2009). Benzer şekilde, Adegbenro (2015) tarafından bildirildiği üzere, Moringa oleifera, Ocinum gratissimum, Manihot esculenta, Telfaria occidentalis ve Vernonia amygdalina yaprak ununun %5'e kadar kullanımı iştah açıcı olarak etki etmiş, sağlıklı yaşamı kolaylaştırmış ve tavuk üretimini, yumurta sarısı rengini ve lezzetini artırmıştır.

Yumurta tavuklarının diyetine %1.5-2 oranında Tanacetum balsamita eklenmesi, hem yumurta sarısı rengi hem de tavukların üretim performansı ve kan göstergeleri üzerinde olumlu etkiler sağlamıştır (Nobakht ve Moghaddam, 2013).

Fitojenik yem katkı maddeleri, etlik piliçlerde vücut ağırlığını, fagositik aktiviteyi ve antioksidan enzim seviyelerini önemli ölçüde artıran kekik ile yapılan diyet takviyelerinin, patojenlere karşı antimikrobiyal etkileri nedeniyle önemli olduğu ortaya konmuştur (Sadek ve ark., 2014). Fitojenik yem katkı maddeleri veya bitki özleri, daha güvenli ve sağlıklı olduklarına inanıldığı için yem endüstrisinde giderek popülerlik kazanmaktadır. Bu fitojenik katkı maddeleri, tıbbi bitkilerin, baharatların veya diğer bitkilerin yapraklarından, köklerinden, yumrularından veya meyvelerinden elde edilen heterojen bir yem katkı maddeleri grubu olarak karşımıza çıkmaktadır. Bütün, kurutulmuş ve öğütülmüş formda veya özüt ya da uçucu yağlar olarak mevcuttur. Bu yem

katkı maddelerinin özellikle domuz ve kümes hayvanlarında kullanımı son zamanlarda önem kazanmıştır (Jamroz ve ark., 2006).

Bir başka çalışmada ise, fesleğen, kekik ve adaçayı esansiyel yağlarının etlik piliç diyetlerindeki etkilerinin değerlendirildiği çalışmada, uyluk etindeki antioksidan kapasitesinin, toplam polifenol içeriğinin ve toplam n-3 ve n-6 çoklu doymamış yağ asitlerinin arttığı gözlenmiştir (Vlaicu ve ark., 2023).

Gıda güvenliği, çevre kirliliği ve genel sağlık riskleri hakkındaki artan endişeler nedeniyle, son yıllarda hayvan yemlerinde büyümeyi teşvik etmek amacıyla kullanılan antibiyotikler yasaklanmıştır. Sonuç olarak, hayvan bilimcileri ve üreticileri büyümeyi teşvik eden, et kalitesini iyileştiren ve hayvanların sağlığını artıran alternatifler aramışlardır. Bitki özleri, doğal olmalarının sağladığı faydalar nedeniyle günümüzde yem katkı maddesi olarak oldukça fazla ilgi görmektedir. Fitojenik yem katkı maddeleri arasında esansiyel yağlar, terpenoidler (mentol, linalool, geraniol, borneol, -terpineol) ve düşük molekül ağırlıklı alifatik hidrokarbonlar (timol, karvakrol, öjenol, sinnamaldehit) gibi düzinelerce bileşenden oluşan uçucu bileşiklerin karışımları, canlı organizmalar tarafından üretilmekte ve bir bitkinin tamamından veya bitkilerin belirli kısımlarından izole edilmektedir (Amiri, 2012). *Ocimum basilicum, Thymus vulgaris* ve *Salvia officinalis* gibi Lamiaceae veya Labiatae'den elde edilen esansiyel yağlar, tavukların diyetlerinde fitojenik yem katkı maddesi olarak yoğun bir şekilde kullanılmaktadır. Farklı esansiyel yağlar gerek tek başına gerekse broiler tavuk yemlerine eklenerek kullanıldıklarında üretim performanslarını (Smits ve ark., 1998; Jamroz ve ark., 2005) immünolojik durumu (Cook ve Samman, 1996; Bento ve ark., 2013), kan serumundaki ve kan lipit profilindeki enzimatik aktiviteyi (Guo ve ark., 2004; Abdulkarimi ve ark., 2011) ve bağırsak morfolojisini (Sadeghi ve ark., 2011, Azwanida ve ark., 2015) olumlu yönde etkilediği bildirilmiştir. Erkek broiler piliçlerde çeşitli kekik türlerinin *Thymus daenensis, T. kotschyanus, T. lancifolius* ve *T. transcaspicus*) hidroalkolik ekstraktlarının etkisi değerlendirilmiş ve *T. daenensis* verilen piliçlerin en iyi ağırlık kazanımına sahip olduğu gözlenmiştir. *T. daenensis* ekstraktı ilave edilen diyet, organik materyalin sindirilebilirliğini artırmış ve kuru madde, ham karbonhidrat, ham kül ve eter ekstraktı değerlerinde iyileşmeye neden olmuştur. Çalışma sonuçları broiler piliçlerin kekik ekstraktlarından etkilenmesinin civcivin yaşına ve bitkinin genotipine bağlı olduğunu ortaya koymuştur (Malekzadeh ve ark., 2018). Esansiyel yağların piliçlerde sindirim enzimlerinin salgılanmasını uyardığı (Dorman ve Deans, 2000; Al-Kassie, 2009), yağ (Smits ve ark., 1998) ve amino asit sindirilebilirliğini artırdığı gözlenmektedir (Jamroz ve ark., 2005). (Malekzadeh ve ark., 2018). Ayrıca flavonoid açısından zengin olan kekik bitkisinin kümes hayvanlarının bağışıklık ve savunma sistemi üzerinde düzenleyici etkisi gözlenmiştir (Cook ve Samman, 1996).

Fitojenik yem katkı maddeleri, geviş getiren hayvan performansını, rumen fermantasyonunu, süt üretimini, üreme sağlığını, kan profillerini, antioksidan ve antimikrobiyal özelliklerini, bağışıklığı ve et kalitesini iyileştirmektedir. Fitojenik yem katkı maddelerindeki esansiyel yağlar, polifenoller ve flavonoidler gibi belirli biyoaktif bileşikler önemli antimikrobiyal, antifungal, antioksidan ve antiparaziter özellikler göstermektedir Ayrıca ruminal fermantasyonu düzenlemekte, metan emisyonunu azaltmakta, yem alımını ve lezzetini artırmaktadır (Nastoh ve ark., 2024).

Tıbbi ve aromatik bitkiler, antik çağlardan beri yaşam koşullarını iyileştirerek toplumların gelişimine önemli ölçüde katkıda bulunmuştur. Fitojenik bileşimler, hayvan sağlığını ve büyümesini olumlu yönde etkileyen bitki kaynaklı biyoaktif maddelerdir. Bu maddeler tipik olarak uçucu yağlar ve bitkilerden elde edilen özler şeklinde kullanılmaktadır (Nastoh ve ark., 2024). Ayrıca bazılarının antioksidan, antimikrobiyal, antifungal ve antiviral özelliklere sahip olduğu düşünülmektedir (Yang ve ark., 2015). Fitojenik, fitobiyotik ve fitokimyasallar, performansı ve karlılığı artırmak için hayvancılık diyetlerine eklenen, bitki kaynaklı doğal biyoaktif bileşiklerdir (Lillehoj ve ark., 2018). Bu bileşikler anason, karanfil, kekik veya melisa gibi baharatlardan, bitkilerden ve uçucu yağlardan elde edilmektedir (Steiner ve Syed, 2015).

Hayvan yemlerinde çoğunlukla Lamiaceae, Apiaceae, Rosaceae, Asteraceae; diğer yaygın bitki familyaları arasında Alliaceae, Brassicaceae, Cannabaceae, Fabaceae, Gentianaceae, Lauraceae, Myrtaceae, Papaveraceae, Rosaceae, Solanaceae, Zingiberaceae ve sınırlı dağılıma sahip bazı türler bulunmaktadır (Franz ve ark., 2020). Tıbbi ve aromatik bitkiler ve özleri, geviş getiren hayvanların üretimini ve yem kullanımını artırmak için yenilikçi yöntemler sunarken, süt ve et gibi ürünlerinin kalitesini rumen sindirimine etkide bulunarak iyileştirmektedir (Skoufos ve ark., 2020). Fitojenik bileşikler, özellikle uçucu yağlar ile birleştirildiğinde, artan lezzet ve aroma ile lezzetliliği iyileştirerek yem alımını potansiyel olarak artırabilir.

Yenidoğan Holstein buzağılarının mayasına prebiyotik (kobalt laktat ve arabinogalaktonlar) ve uçucu yağ (karvakrol, karyofilen, p-simet, sineol, terpinen ve timol) eklenmesi, yem dönüşüm oranında, kuru madde alımında ve ortalama günlük kazanımda doğrusal bir artışla birlikte vücut çerçeve ölçümlerinde artışa neden olmuştur (Liu ve ark., 2020). Benzer sonuçlar, sıcaklık stresi altındaki kuzulara %1-2 oranında tarçın, zerdeçal, biberiye ve karanfil tomurcuğu karışımının uygulanması yem dönüşüm oranında, kuru madde alımında ve vücut ağırlığında iyileşmeye yol açmıştır (Hashemzadeh ve ark., 2022).

Koyunların diyetlerine 300 mg/kg kekik uçucu yağı eklendiğinde koyunların büyüme performansı, bağırsak florasının yapısı ve bileşiminin iyileştiği gözlenmiştir (Sun ve ark., 2022).

Kekik, biberiye, kekik, kişniş, sarımsak, okaliptüs, anason, karanfil, nane, tarçın, zerdeçal gibi yaygın olarak kullanılan bitkiler, özellikle antioksidan ve büyüme destekleyicileri olarak tatmin edici sonuçlar göstermiştir.

Ayrıca dut, nar ve üzüm çekirdeği gibi meyve özlerinin performansı, sindirilebilirliği, süt üretimini, bağışıklığı ve antioksidan durumunu olumlu yönde etkilediği ortaya çıkmıştır. Fakat, bitki özlerinin kullanımı, sınırlı üretime sahip olması, gelişmiş ekstraksiyon teknolojilerinin olmaması, türe, ağırlığa ve yaşa dayalı belirsiz dozaj yönergeleri, yüksek maliyet ve tutarsız etkiler dahil olmak üzere çeşitli zorluklarla karşı karşıya kalınmaktadır (Nastoh ve ark., 2024).

Tıbbi bitkiler kümes hayvanlarının performansını, bağırsak morfolojisini, besin sindirilebilirliğini ve bağırsak mikrobiyotasını olumlu yönde etkilemiştir (Abd El-Latif ve ark., 2013; Belenli ve ark., 2015; Franciosini ve ark., 2016; Ri ve ark., 2017). Tarçın takviyesi broylerlerde vücut ağırlığı artışını önemli bir şekilde artırmıştır (Singh ve ark., 2014). Kanani ve ark. (2016) yemlere %0.5 tarçın eklenmesinin yem alımının arttığı saptanmıştır. Benzer şekilde etlik piliç diyetlerine biberiye eklenmesi, yem verimliliğini olumlu yönde etkilemiştir (Petricevic ve ark., 2018).

Kümes hayvanı üretimi için fitojenik yem katkı maddesi olarak en çok kullanılan baharatlar ve otlar sarımsak, nane, kekik, yaban turpu, acı biber, tarçın, biberiye, kırmızıbiber, karabiber ve adaçayıdır ve ilgili bitki özleri uçucu yağlar şeklinde kullanılmaktadır (Windisch ve ark., 2008).

Biberiye özleri, kümes hayvanlarında yem dönüşüm oranını, karkas kalitesini ve körbağırsak mikrobiyolojik bileşimini iyileştirmektedir. Biberiye yaprak unu özütü, kümes hayvanı ürünlerinde acılaşma görünümünü geciktirmektedir. Ayrıca kümes hayvanı diyetlerinde büyümeyi teşvik etmek ve kuşların bağışıklık tepkisini artırmak için uygulanmaktadır (Petricevic ve ark., 2018).

Kümes hayvanı diyetine uçucu yağların eklenmesi, büyüme performansını, vücut ağırlığını artırmaktadır (Gopi ve ark., 2014). Birçok uçucu yağ, yararlı mikropların büyümesini teşvik etmekte, terpenoidler ve fenolik maddeler gibi patojenik mikropların büyümesini engellemekte veya sınırlamakta, membran bozulmasını önlemekte ve kümes hayvanlarında patojenik bakterilerin büyümesini engellemektedir (Krishan ve Narang., 2014).

Sonuç

Sonuç olarak, fitojenik yem katkı maddeleri, yem endüstrisinde giderek daha fazla önem kazanmakta ve popülerlik kazanmaktadır. Bu katkı maddeleri, doğal olmaları, güvenli ve sağlıklı olmaları nedeniyle tercih edilmektedir. Kekik, zerdeçal, sarımsak, tarçın ve diğer bitkisel bileşenler, kümes hayvanlarının ağırlık kazanımı, yem dönüşüm oranı, bağışıklık sistemi ve genel sağlık durumları üzerinde olumlu etkiler göstermektedir. Bununla birlikte, fitojenik yem katkı maddelerinin etkili ve güvenli dozlarının belirlenmesi, farklı bölgelerde yetişen bitkilerin ve hasat dönemlerinin standartlaştırılması gibi konular hala araştırma gerektirmektedir. Gelecekte, bu katkı maddelerinin hayvan sağlığı ve performansı üzerindeki etkilerini daha iyi anlamak ve optimize etmek amacıyla daha fazla çalışma yapılması gerekmektedir.

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Combined Effects of Grafting and Vermicompost on Nutrient Composition in Eggplant under Drought Stress and Its Correlation with Yield

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Abstract

Drought poses an increasing threat to global food production, necessitating sustainable agricultural practices to reduce yield and quality losses. In this study, the synergistic effects of grafted seedlings and vermicompost-V on the nutrient content of eggplant plants and their relationship with yield were investigated. The study was carried out with eggplant seedlings (grafted-G) and non-grafted-NG) in pots containing vermicompost-V (V_0: 0%, V_1: 1%, V_2: 2%, V_3: 3%) under three different drought levels (100% irrigation-, 70% irrigation, mild drought stress - MS) and 30% irrigation, severe drought stress-SS) as irrigation. The findings showed that the interaction of 'grafting x vermicompost x drought' created statistically significant differences in terms of N, P, K, Mg, Fe, Cu and Mn contents. Higher increases were observed in grafted plants under stress compared to the control due to vermicompost application. The most striking increases were 50.56% and 45.67% for N; 110.08% and 96.59% in G x V_3 under SS conditions. In terms of P content, under SS had a 116.50% increase in G x V_3. There was an increase. In terms of K content, 115.69% and 111.16% increases were evident in MS and SS in G x V_2. However, positive correlations were observed between K and N, P and Mg; Mn and Fe and Cu; Fe and Cu. On the other hand, weak and negative correlations were determined between yield and N and K; and high positive correlations were determined between Mn, Fe and Cu. The polar heatmap with dendrogram revealed that macro (N, P, K, Mg) and micro (Fe, Mn, Cu) nutrients were clustered in different groups. While a direct relationship was observed between yield and Fe, Mn and Cu, an indirect relationship was determined with N, P, K and Mg. The findings showed that grafting and vermicompost applications increased nutrient uptake under drought stress conditions and there was a close relationship between yield and nutrient elements. The results are important in terms of revealing the positive effects of sustainable agricultural practices on plant nutrition and yield in drought.

Key Words: *Eggplant, drought, vermicompost, grafted plant, correlation, yield*

Introduction

Drought, as one of the important abiotic stresses, occurs when rainfall is insufficient and evaporation exceeds water intake, and negatively affects plant growth, yield, and quality, eventually leading to plant death. Under drought stress, significant changes occur in leaf area, stomatal density, relative water content, stomatal conductance, and chlorophyll concentration in vegetables (Ors et al., 2021; Hannachi et al., 2022; Kıran and Baysal Furtana, 2023). In addition, drought significantly affects the uptake and utilization of macro (N, P, K, Mg) and micro (Fe, Mn, Cu) nutrients by disrupting water balance, restricting nutrient mobility, and impairing root function, and ultimately causes reduced plant growth and yield (Ors et al., 2021; Hannachi et al., 2022).
Eggplant (Solanum melongena) is the third most important vegetable in the Solanaceae family in terms of production (Sekara et al., 2007). Although eggplant is moderately drought resistant, prolonged drought can negatively affect plant growth and yield by disrupting metabolic activities. The use of cultivars tolerant to drought stress is an important strategy to reduce yield and quality losses. However, since this trait is controlled by many genes, it is difficult to develop drought-tolerance cultivars (Toppino et al., 2022). Grafting in eggplant can control the stomatal regulation system in plant transpiration under drought stress quite well depending on the combination of rootstock and scion and can reduce drought damage (Boyaci and Ellialtıoglu, 2018). Although grafting increases product yield and quality under water-limited conditions, it may not be sufficient alone when drought is severe. Grafting onto drought-resistant rootstocks and the use of vermicompost can increase the adaptation of plants to stress conditions. At this point, vermicompost reduces the water requirement of the plant by increasing the moisture

retention capacity of the soil (Demir, 2019) and strengthens stress tolerance by improving soil fertility (Rehman et al., 2023) (Kıran, 2019).
In this study, the effects of the combined use of grafting and vermicompost on nutrient uptake in eggplant and how these changes are related to each other and yield were investigated. The findings are important for sustainable agricultural practices and contribute to the development of plant nutrition strategies in stress conditions such as drought.

Materyal ve Yöntem

The study was carried out between April and July 2020 in the greenhouse conditions of the Soil, Fertilizer and Water Resources Central Research Institute. Temperature and humidity control were provided automatically in the greenhouse environment. Grafted and ungrafted eggplant seedlings of the Aydın Siyahı variety on the Köksal F1 rootstock constituted the plant material. The grafting process was carried out by Antalya Tarım A.Ş. When the grafted and ungrafted seedlings reached 3-4 true leaves, they were planted in 39x35 cm and 35 L volume polyethylene pots containing clayey soil (1 seedling/pot). 15 days before planting, vermicompost was added to the pots at the rates of 1%, 2% and 3% of the soil weight. Vermicompost (organic matter: 39.2%, total phosphorus: 0.21%, total potassium: 0.94%, EC: 5.62 dS m-1, pH: 6.62) was supplied by Ekosol Tarım ve Hayvancılık A.Ş., Manisa. Stress treatments were started 15 days after seedling planting and continued for 110 days. The study was carried out in randomized plots according to factorial experimental design with 3 replicates. Factors: 1. Grafting (grafted-G, non-grafted-NG plants), 2. Vermicompost application (V0: 0%, V1: 1%, V2: 2%, V3: 3% (w/w)), 3. Drought stress (100% irrigation-well watered,WW), 70% of the water given to control (mild drought stress- MS) and 30% (severe drought stress - SS). The water amount of the pots was determined on the basis of weight. Before applying drought stress, all plants were watered at field capacity level and stress was created by applying limited irrigation with different water amounts. MS and SS subjects were given 70% and 30% of the water amounts given to the control, respectively. Field capacity was taken as the basis for irrigation. The total weight of the pots was determined when the soil moisture content was at field capacity and wilting point levels. Daily pot weighing was done to monitor the amount of water lost and the amount of water lost was completed in accordance with the subject. According to the soil analysis results, the deficient fertilizer need of the plants was met.
N, P, K, Ca, Fe, Zn, Cu analyses were carried out in plant leaf samples. Total N amount was determined in dried and ground leaf samples using the Leco TruSpec-CHN device according to the Dumas method. For P, K, Ca, Fe, Zn, Cu analyses, leaf samples were weighed as 0.25 g and wet-digested with nitric acid (HNO_3) in a microwave device, then these samples were transferred to a 50 ml container and the volume was completed with deionized water and filtered through blue band filter paper. Total K was determined in the plant solution obtained using the wet-digested method using the Jenway PFP 7 Flame photometer (Kacar and İnal, 2008). Total phosphorus in the plant solution obtained using the wet-digested method was determined using the Shimadzu UV-160 Spectrophotometer according to the vanadomolybdenum phosphoric yellow color method (Kacar and İnal, 2008). Ca, Fe, Cu, Zn contents in the filters obtained according to the burning method were determined in Varian 720-ES ICP-OES (Kacar and İnal, 2008).
Total yield (kg plant^{-1}): Fruits collected from the first harvest to the last harvest date of each application subject were weighed. The obtained values were collected cumulatively and total yield per plant (kg plant^{-1}) was calculated.
The numerical data obtained from the experiments were subjected to variance analysis using MSTAT-C software, and differences were expressed with Duncan's multiple comparison test. Correlation analysis was performed to evaluate the relationships between the examined traits and expressed with a heatmap. The clustering between the variables was visualized with a dendrogram polar heatmap. Origin-2024 (Northampton, MA, USA) software was used for both analyses.

Bulgular ve Tartışma

The effects of grafting x vermicompost x drought stress interaction on N, P, K, Mg, Fe, Cu and Mn contents and yield were found to be statistically significant ($p<0.05$) (Table 1). However, there was no significant effect in terms of Ca content ($p>0.05$) (Table 1). Drought stress caused a slight increase in N, P, K and Mg contents of ungrafted and vermicomposted plants. These increases can be attributed to the increase in nutrient concentration with the decrease in water, changes in root morphology and adaptive mechanisms of the plants. However, combined grafting and V applications caused increases in macro and micro element contents compared to control (ungrafted and without vermicompost = without G and without V). Especially as the vermicompost dose increased, higher N, P, K and Mg accumulations were observed in the leaves of grafted plants under stress. Nitrogen content increased by 50.56% and 45.67% under MS and SS at G x V3 dose compared to control. The highest increase in phosphorus content was observed in G x V3 combination with 116.50% in SS, while K content increased by 115.69% and 111.16% with G x V2 application under MS and SS. While Mg concentration decreased significantly in SS

medium, a significant increase of 53.80% was obtained with G x V1 application under MS. It was thought that N content might have increased more for the synthesis of special proteins effective in the stress tolerance mechanism of grafted plants under stress (Da Silva et al., 2011). The improved root structure of the grafted plants and the increased mineralization due to the use of vermicompost had a positive effect on the N uptake of the plants. The addition of vermicompost to the growing medium increased P mineralization in the soil and ensured its transformation into a useful form in the soil, allowing the grafted plants to take phosphorus more easily (Uma and Malathi, 2009; Farahani et al., 2020) and supported the stress tolerance of the plant. In addition, the effective root system of the Köksal F1 eggplant rootstock, which is a S. incanum hybrid used in grafting the plants, made a significant contribution to the tolerance to drought stress. Grafting onto a suitable rootstock is effective as a technique that increases drought tolerance, and in a previous study, this rootstock positively affected the drought stress tolerance of the grafted variety (Kıran et al., 2017). Vermicompost applications increase the usefulness of nutrients in the soil due to the activity of microorganisms responsible for the fixation, mineralization or dissolution of the nutrients it contains and the presence of high molecular weight acids that help dissolve some nutrients in the soil, and reduce the leaching of nutrients due to the increase in the negative charges of the soil by OH- in worm compost (Cruz et al., 2024). The emergence of more K and Mg accumulations with the use of vermicompost in eggplant plants grafted onto strong rootstocks can be attributed to the fact that stressed plants accumulate more K and Mg ions in their bodies in order to maintain turgor pressure, ion homeostasis and continue photosynthesis. Rootstocks used in grafted plants provide stress tolerance by increasing stomatal regulation and capacity in leaves by increasing K uptake (Mengel et al., 2001). In fact, there is information in the literature that vermicompost, as an organic material rich in K, has the ability to improve soil properties (Sinha et al., 2010).

Table 1. Variance analysis results of macro and micro elements

Source of Variation	*sd*	N	P	K	Ca	Mg	Mn	Fe	Cu	Yield
Grafting (G)	1	**	**	**	ns	**	**	**	**	**
Vermicompost (V)	3	**	*	ns	*	**	*	**	**	**
Drought stress (DS)	2	**	**	ns	*	ns	*	**	**	**
G × V	3	**	**	**	**	*	**	**	**	**
G × DS	2	**	*	ns	ns	**	ns	ns	**	**
V × DS	6	**	**	ns	*	**	ns	**	*	*
G × V × DS	6	**	**	*	ns	**	*	**	**	*
Error	48	0.04	0.00	0.17	0.05	0.04	45.91	198.41	0.76	0.020
CV(%)		5.99	8.22	9.76	6.22	12.23	9.27	13.31	6.85	11.29

ns: not significant. * p 0.05, **p 0.01.

Table 2. Effect of 'grafting × vermicompost × drought' interaction on macro, micro elements and yield

Grafting	V (%)	DS	N (%)	P (%)	K (%)	Mg (%)	Mn (ppm)	Fe (ppm)	Cu (ppm)	Yield (kg plant^{-1})
Non-grafted	0 (V_0)	WW	2.38 jk	0.120 hı	2.38 kl	1.44 e-g	71.37 n	81.98 h-k	11.37 j	1.22 e
		MS	2.67 ıj	0.127 gh	2.55 ı-l	1.58 c-g	63.43 r	76.16 ı-k	8.95 m	0.93 fh
		SS	2.89 a-c	0.103 ı	2.51 c-g	1.98 bc	57.27 u	66.63 k	9.54 l	0.34 h
	1 (V_1)	WW	3.03 g-ı	0.143 fg	2.9 l	1.66 b-g	73.92 m	101.84 f-ı	12.11hı	1.65 bc
		MS	3.48 d-f	0.197 b-d	4.35 c-ı	1.85 b-e	73.02 m	77.06 h-k	11.53 j	1.21 e
		SS	3.80 b-d	0.180 de	4.37 c-h	1.78 b-e	65.68 p	73.66 jk	11.75 ıj	0.36 h
	2 (V_3)	WW	3.19 f-h	0.150 f	3.89 f-k	1.34 fg	60.60 s	96.55 f-j	15.85 a	1.63 b-d
		MS	3.46 d-f	0.133 f-h	4.01 f-k	1.62 c-g	56.40 w	80.64 h-k	11.43 j	1.38 de
		SS	3.29 e-g	0.190 c-e	4.27 d-j	1.61 c-g	56.75 u	76.67 ı-k	9.55 l	0.54 gh
	3 (V_4)	WW	3.53 c-f	0.120 hı	3.65 h-l	1.27 g	71.40 n	160.91 b	14.43 cd	1.71 b
		MS	3.71 b-d	0.173 e	4.14 d-k	1.67 b-g	64.05 q	135.55 b-d	9.48 l	1.38 de
		SS	4.06 ab	0.20 bc	4.80 a-e	1.64 b-g	59.09 t	85.57 g-k	10.27 k	0.54 gh
Grafted	0 (V_0)	WW	2.23 k	0.19 bc	3.73 g-k	1.64 b-g	85.01e	104.25 f-h	15.77 a	1.63 b-d
		MS	3.32 f-g	0.227 a	4.54 b-f	1.93 b-d	78.00 h	109.33 e-g	13.09 f	1.42 c-e
		SS	3.24 e-g	0.203 bc	4.89 a-d	2.04 b	77.59 ı	82.56 g-k	14.27 cd	0.38 h
	1 (V_1)	WW	2.74 ı	0.180 de	3.82 f-k	1.53 c-g	88.38 b	88.79 g-k	14.37 cd	1.78 b
		MS	3.25 e-g	0.187 c-e	4.82 a-e	2.43 a	74.16 l	90.52 g-k	13.81 e	1.60 b-d
		SS	3.70 b-d	0.200 bc	4.91 a-d	1.81 b-e	80.77 g	68.14 k	12.46 gh	0.41 h
	2 (V_2)	WW	2.88 hı	0.202 bc	3.54 j-k	1.54 d-g	95.36 a	137.19 b-d	14.13 de	2.53 a
		MS	3.60 c-e	0.193 b-d	5.50 a	1.83 b-e	84.70 f	149.87 bc	14.50 c	1.80 b
		SS	3.72 b-d	0.210 ab	5.30 ab	1.70 b-f	65.94 p	118.27 d-f	12.81 fg	0.83 f
	3 (V_3)	WW	2.77 ı	0.173 e	3.59 h-l	1.62 c-g	86.54 d	186.43 a	15.17 b	2.50 a
		MS	4.02 ab	0.180 de	4.07 e-k	1.87 b-d	87.65 c	160.00 b	15.25 b	1.84 b
		SS	4.21 a	0.223 a	5.15 a-c	1.73 b-f	75.62 j	130.99 c-e	13.80 e	0.76 fg

The variance between the means expressed with different letters is significant (p<0.05).

In the study, as in Mn content, increasing losses were also observed in Fe and Cu contents with stress and increases were obtained in the amount of these elements under stress conditions thanks to the interaction of grafting and vermicompost. In terms of Mn content, G x V1 provided 41.36% increase in SS. A similar trend was observed in Fe and Cu concentrations and the highest increase rates were realized in MS and SS conditions with G x V3 (110.08% and 96.59%; 70.89% and 44.84%) (Table 2). Root hydraulic conduction in grafted plants and developed root system of the rootstock provided increases in Mn, Fe and Cu contents. In the study, Fe and Mn uptake by plants remained at low levels in SS and was relatively higher in MS. Vermicompost enriched the soil in terms of Fe and Mn and helped the availability of nutrients in dry conditions by secreting plant growth regulators in the plant rhizosphere thanks to the beneficial microorganisms it contains (Rangarajan et al., 2008). Similar results were reported by Tang (2018) and Kıran et al. (2017).

In the study, it was also examined how the changes in nutrient contents are related to each other and to yield, for this purpose, correlation analysis was performed and the results are given in Figure 1. In the correlation analysis; positive relationships were observed between K and N and P; Mg and K; Mn and Fe and Cu. However, the correlation between nutrient contents and yield was also examined. While it was noted that yield exhibited weak negative relationships with macro elements N and K, it was determined that it showed relatively strong positive relationships with Mn, Fe and Cu. The negative correlation between N and K and yield suggests that excessive N or K accumulation, especially under drought conditions, may have negative effects on plant growth. Although N and K are critical nutrients for plant growth under normal conditions, they may have negative effects under drought stress. N is necessary for protein synthesis, photosynthesis and growth in the plant. However, excessive N intake can promote vegetative growth under drought conditions; this situation can reduce stress tolerance by increasing water loss. In addition, excessive N can cause carbon and nitrogen imbalance, negatively affecting the synthesis of osmoprotectants (proline, sugar, etc.) and thus reducing drought tolerance (Du et al., 2017). As a result, it is possible that the yield will be low and a negative correlation will occur. On the other hand, the relationship between high K levels and reduced yield may be due to antagonistic nutrient interactions. The relatively strong positive correlation between Mn, Fe, and Cu and yield indicates that these microelements play critical roles in stress tolerance and metabolic processes. Mn, Fe, and Cu are micronutrient elements that play an important role in drought tolerance, and high levels of these elements are seen as factors that positively affect yield. Mn deficiency can negatively affect photosynthesis and carbon metabolism; however, high levels of Mn may have increased yield by protecting these processes (Messant et al., 2022). High Fe levels in drought conditions can reduce chlorosis and increase photosynthetic capacity. High Fe can support ATP production by improving photosynthetic electron transport and contribute to yield by providing energy balance under stress conditions (Briat et al., 2015). In addition, Cu is necessary for lignin synthesis and cell wall stability (Li et al., 2023). Under drought stress, plants can contain more Cu against oxidative stress, which can prevent cell damage and help maintain growth (Chen et al., 2022).

The polar heatmap with dendrogram visualizes the relationship between yield and nutrients in grafted/non-grafted plants and vermicompost applications at different drought levels (Figure 2). Temperature differences in the polar heatmap indicate clustering; if high temperatures (red tones) are concentrated in a certain area, this may indicate that the area forms a cluster. Similarly, low temperatures (blue tones) may also show a tendency to cluster. The clustering structure of nutrients reveals that certain elements act together. In this context, macronutrients (N, P, K, Mg) and micronutrients (Fe, Mn, Cu) were located in different groups and exhibited direct relationships among themselves. However, while high nutrient intake represented by dark red came to the fore in control conditions, it was observed that nutrient intake decreased in MS (light red tone) and MS conditions (blue tone). The dendrogram in the heatmap shows that red tones are more dominant in grafted plants grown in vermicomposted environments, meaning that nutrient uptake is better maintained under drought conditions and yield is higher. This is a result of the synergistic interaction between the fact that grafted plants generally have a stronger root system and can increase nutrient uptake under stressful conditions, and the fact that vermicompost improves soil structure and supports plant nutrient uptake. The fact that the color tone does not shift to blue, especially under drought conditions, reveals the power of the synergy of grafting and vermicompost. On the other hand, the fact that blue areas are more common in non-grafted and low vermicompost doses shows that nutrient loss is more pronounced in these groups and yield losses increase due to stress.

In conclusion, our findings suggest that the interaction of grafting, vermicompost and drought stress significantly affects nutrient uptake and yield. Grafted plants grown in vermicompost enriched soil maintained higher nutrient levels and yield under drought stress as expressed by the predominance of red tones in the heatmap. The clustering pattern also revealed strong positive correlations between micronutrients (Fe, Mn, Cu) and their relationship with yield, while excessive N and K accumulation showed a weak negative correlation with yield under drought conditions.

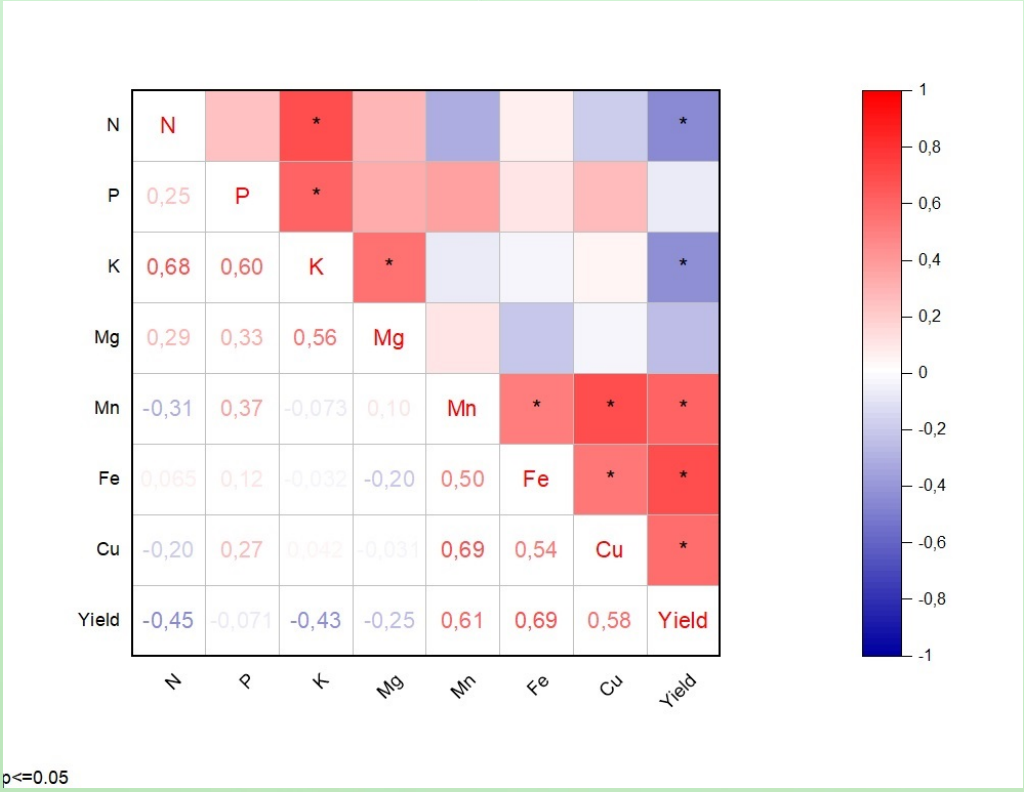


Figure 1. Correlation table between macro and micro element contents and yield.

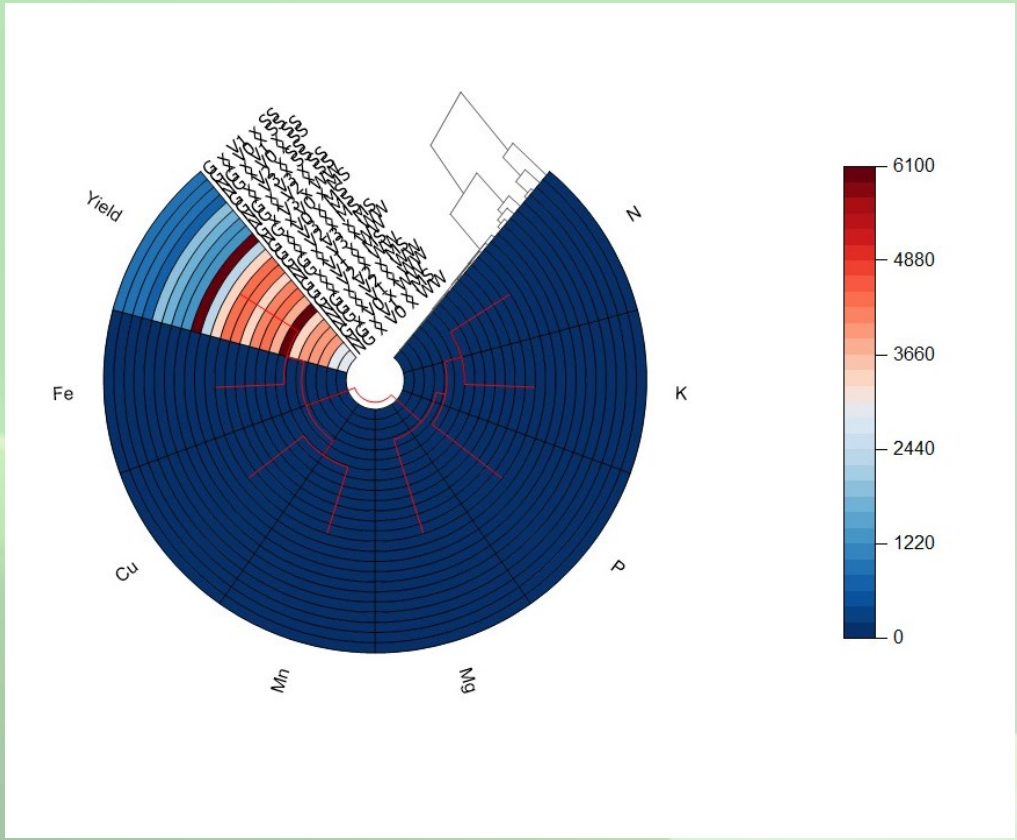


Figure 2. Representation of the relationships between macro and micro element contents and yield with dendrogram polar heatmap

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ID: 382

Colorimetric Detection of Biogenic Amine Formation by Various *Bacillus* Strains Isolated from Tarhana

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Abstract

Biogenic amines are nitrogenous substances produced through the decarboxylation of amino acids by the action of substrate-specific amino acid decarboxylases. They are health-threatening substances, and excess consumption can cause health problems such as nausea, respiratory distress, hot flush, sweating, heart palpitations, headache, hyper/hypotension, etc. Various groups of microorganisms, including lactic acid bacteria, *Enterococcus*, *Bacillus*, and *Pseudomonas*, have been reported to have amino acid decarboxylase activities. The risk of biogenic amine formation is especially high in fermented foods. Moreover, it can also be found in some raw foods. Amongst the biogenic amines, cadaverine, histamine, putrescine, and tyramine are the most common, which are formed by the decarboxylation of lysine, histidine, ornithine, and tyrosine, respectively. In this study, biogenic amine formation abilities of various *Bacillus* strains isolated from tarhana samples were detected. For this purpose, a colorimetric method was applied, which is based on the pH shift (increase) upon the formation of biogenic amines in the presence of a pH indicator dye (bromocresol purple). The bacteria were cultivated in Luria Bertani broth at an initial pH of 5.0 containing precursor amino acids, namely lysine, histidine, ornithine, and tyrosine. At the end of 24 h incubations at 37 °C with agitation at 60 rpm, absorbances of the cell-free supernatants were measured at 590 nm. The highest absorbance values were recorded as higher biogenic amine formation. Control samples without precursor amino acids were also prepared. The percent increase in the absorbance was the rate of biogenic amine formations. Ninety-five *Bacillus* isolates were tested for four biogenic amine formations. The results showed that the type and the amount of biogenic amine production in *Bacillus* were directly related to the organisms.

Key Words: *Biogenic amine, Bacillus, Cadaverine, Putrescine, Histamine, Ornithine*

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ID: 383

Isolation and Identification of *Bacillus* Strains from Various Tarhana Samples

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Abstract

Tarhana is a Turkish fermented food that is consumed extensively all over the country. It is mainly produced by fermenting the dough prepared using wheat flour, yogurt, water, some vegetables, and spices. Then the fermented dough is dried and consumed as soup after grinding. There are many different types of tarhana depending on the region. The main fermentation microorganisms in tarhana are lactic acid bacteria and yeasts. However, in this study we have intended to isolate *Bacillus* strains from tarhana samples. Strains of the genus *Bacillus* are Gram-positive, endospore-forming aerobic or facultatively anaerobic, and generally found in soil. They have substantial applications in the industry owing to their multifunctional properties, including the production of various enzymes, exopolysaccharides, antimicrobial substances, etc. In the study, more than 80 tarhana samples were collected from different regions in Türkiye. For the isolation, diluted samples were kept at 80 ºC for 30 min to destroy non-spore-forming microorganisms. The serial dilutions were prepared and inoculated on nutrient agar plates. Then they were incubated at 37 ºC for 24 h. Typical colonies were chosen and streaked again on nutrient agar plates and incubated. These procedures were repeated thrice in order to assure the selection of single colonies. A total of 480 microorganisms were isolated. The isolates were deposited in 25% glycerol at -45 ºC. Gram staining, spore-formation, catalase, and motility tests were applied to confirm the *Bacillus* isolation. The results revealed that the tarhana is also a rich source of *Bacillus* strains. Moreover, the amylolytic and proteolytic activities of the isolates were also determined, and the majority of the isolates were able to produce amylase and proteases.

Key Words: *Tarhana, Bacillus, Isolation, Identification*

Acknowledgment: This study was supported by the Scientific and Technological Research Council of Türkiye (TUBITAK). Grant no: 123 O 924.

ID: 384

Allelopathy and Agronomy: An integrated Approach for Sustainable Management of Little Seed Canary Grass (*Phalaris minor* Retz.) in Wheat Cropping System of Pakistan

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Abstract

Allelopathy, the chemical interaction between plants, offer a promising approach for sustainable weed management, aligning with the congress's focus on innovative and eco-friendly agricultural practices. This study investigated the influence of wheat cultivars on little seed canary grass (*Phalaris minor* Retz.) through field experiment and a laboratory study. The field study was conducted during 2010-11 and 2011-12 at the Experimental Farm, Department of Agronomy, University of Agriculture, Faisalabad-Pakistan. It examined the impact of wheat cultivars (Shafaq-06 and Sehar-06 representing high and low allelopathic potential, respectively) sowing at 05 different row spacings (10 cm, 15 cm, 20 cm, 25 cm and 30 cm) on weed suppression. Results demonstrated that narrow row spacing (10 cm and 15 cm) significantly reduced little seed canary grass density and biomass accumulation with Shafaq-06 exhibiting superior weed suppression compared to Sehar-06. The laboratory study was conducted during 2012-13 at the Crop and Soil Sciences Department, Oregon State University, USA. It assessed that allelopathic effect of fresh and boiled water extracts from US Wheat cultivars (Marry, Stephen, Shafaq-06 and Sehar-06) on little seed canary grass seedling growth. Boiled extracts, particularly at 45 days after sowing (DAS), showed stronger inhibitory effects, with Marry and Stephen extracts reducing shoot length by 52% and 48%, respectively, and shoot dry weight by up to 37%. Phenolic compounds analysis confirmed their critical role in allelopathic activity. These findings highlights the potential of high-allelopathic wheat cultivars, such as Shafaq-06, Marry, and Stephen, combined with the optimized row spacing, as effective tools for integrated weed management. This approach supports the Congress's emphasis on reducing reliance on chemical herbicides and promoting sustainable agricultural practices, contributing to environmentally friendly and economically viable farming system.

Key words: *Allelopathy, Sustainable Weed Management, Weed Suppression, Phenolic Compounds, Eco-friendly Agriculture*

ID: 385

Impact of Defatted Sesame Meal on the Technological and Sensory Quality and Antioxidant Activity of Gluten-free Buckwheat Crackers

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Abstract

Currently, a gluten-free diet is the sole successful remedy for celiac disease. However, it is difficult for celiac patients to access commercially functional gluten-free foods. Defatted sesame meal as a by-product of the cold-pressed sesame oil production process is a good option to enrich gluten-free crackers because of its rich protein and fiber content. In the present study, defatted sesame meal was used to develop gluten-free cracker formulations. Gluten-free flour blend containing buckwheat flour:corn starch (7:3, w/w) was substituted with defatted sesame meal at 0, 5, 10, 15 and 20% levels. The effect of defatted sesame meal on the technological properties, antioxidant activity and sensory quality of gluten-free cracker samples were evaluated. The moisture contents of gluten-free buckwheat crackers containing 5, 10 and 15% defatted sesame meal were close to the control (0% sesame meal). The inclusion of sesame meal did not show adversely influence on the diameter and thickness values of buckwheat crackers. Compared to the control, samples made from 10 and 15% sesame meal exhibited higher spread ratio values. Samples with sesame meal exhibited a significantly ($p<0.05$) increased total phenolic content relative to the control. Moreover, crackers prepared from 15% (2.82 µmol TE/g) and 20% (2.90 µmol TE/g) sesame meal showed strong antioxidant properties. Sensory evaluation showed that high levels of sesame meal improved the appearance of crackers compared to the control. The incorporation of sesame meal up to 15% gave comparable overall acceptability to the control. The data revealed that defatted sesame meal (up to 15%) is a good alternative to improve the antioxidant capacity of gluten-free crackers with acceptable technological and sensory quality.

Key Words: *Gluten-free, Crackers, Sesame, By-product, Functional food*

Introduction

Celiac, an autoimmune disease, is one of the most common food intolerances worldwide and can occur at any age (Rivera et al., 2013). The gluten-free market has grown rapidly year on year and is expected to reach 7.5 billion dollars by 2027 (Kajzer and Diowksz, 2021). Developing special products for this market is an important opportunity for manufacturers.

Crackers are one of the popular cereal-based snacks worldwide. They can be easily enriched with functional constituents such as protein- and fiber-rich by-products. Tomic et al. (2022) incorporated pumpkin seed press cake flour into gluten-free chickpea crackers. They found that replacing chickpea flour with pumpkin seed meal improved the protein content and antioxidant activity of crackers, and improved their taste and flavor. Akeem et al. (2023) produced gluten-free crackers using composite flour containing germinated pearl millet+defatted sesame+tigernut flour. They stated that adding composite flour enhanced ash, fiber, protein, and calcium contents of crackers and improved their protein digestibility compared to the control.

Sesame (*Sesamum indicum*) seeds are a good source of unsaturated fat, protein, dietary fiber, vitamins, minerals (iron and calcium) and antioxidant compounds. Also, they contain lignans such as sesamol, sesamolin, sesamin and sesaminol which could exhibit anti-hypertensive, anti-inflammatory, anti-carcinogen and antioxidant features (Wei et al., 2022). Defatted sesame meal is a by-product of cold-pressed sesame oil production. It contains about 50% protein, dietary fibers and bioactive compounds (Melo et al., 2021).

To the best of my knowledge, this study represents the first research on the effect of cold-pressed sesame meal on the quality of gluten-free buckwheat crackers. Therefore, the objective of this study is to develop functional gluten-free crackers by adding defatted sesame meal at 0, 5, 10, 15 and 20% levels, and to investigate the impact of sesame meal addition on the moisture content, diameter, thickness and spread ratio, total phenolic content, antioxidant activity and sensory properties of gluten-free buckwheat crackers.

Materials and Methods

Materials

Light buckwheat flour was supplied from Bulvar Gıda (Konya, Türkiye). Corn starch, shortening, salt, caster sugar, baking powder and yeast were procured from a local supermarket in Konya, Türkiye. Cold-pressed defatted sesame meal was kindly donated by Neva Gıda, İstanbul, Türkiye. Xanthan gum was purchased from Smart Kimya, İzmir, Türkiye.

Methods

Preparation of gluten-free crackers

Gluten-free control crackers (0% sesame meal) were prepared by mixing 250 g of gluten-free flour blend (buckwheat flour:corn starch, 7:3, w/w), 50 g of shortening, 4 g of salt, 3.75 g of caster sugar, 3.75 g of baking powder, 2.5 g of yeast, 2.5 g of xanthan gum and water. Crackers containing defatted sesame meal were incorporated into four different levels (5, 10, 15 and 20%). The dough was fermented at 35°C for 2 h. After that, it was sheeted and cut into a circular shape. Cracker doughs were baked (Kumtel LX-9645, Kayseri, Türkiye) at 175°C for 9 min.

Laboratory analysis

The moisture content of samples was determined by a rapid moisture analyzer (Shimadzu M0C63u, Kyoto, Japan).

Diameter and thickness of crackers were measured via a caliper. To find spread ratio, the diameter was calculated by dividing the thickness.

Phenolic compounds were extracted by the method of Yaver (2023). Two grams of sample were reacted with 20 mL of methanol:distilled water:HCl (8:1:0.1, v/v/v) at 30°C for 2 h. The extracts were subjected to centrifugation (Nüve NF800, Ankara, Türkiye) at 3000 rpm for 10 min. The Folin-Ciocalteu reagent method described by Yaver (2023) was used to determine the total phenolic content of crackers. The antioxidant activity of crackers was determined by the DPPH assay (Yaver, 2023).

Sensory evaluation of gluten-free crackers was carried out by 12 panelists using a 9-point hedonic scale (1; extreme disliking, 9; extreme liking). Panelists assessed the taste, odor, appearance, crispness and overall acceptability parameters.

Statistical analysis

The data were analyzed and compared with the Tukey HSD test at a significance level of $p<0.05$ using JMP 5.0 (SAS, North Carolina, USA).

Results and Discussion

Moisture content and diameter, thickness and spread ratio values of gluten-free buckwheat crackers are given in Table 1. The moisture content of crackers ranged between 6.13% and 6.59%. Compared to the control gluten-free buckwheat crackers, samples containing 20% defatted sesame meal had a slightly higher moisture content. The rich dietary fiber content of sesame meal may be responsible for this increase in moisture content (Melo et al., 2021).

Table 1. Moisture content and technological features of gluten-free crackers

Crackers	Moisture (%)	Diameter (mm)	Thickness (mm)	Spread ratio
Control	6.13±0.10^{b}	49.19±0.44^{a}	1.45±0.21^{a}	33.92±0.20^{c}
5%	6.18±0.08^{b}	49.13±0.54^{a}	1.50±0.25^{a}	32.75±0.25^{d}
10%	6.26±0.06^{ab}	49.29±0.51^{a}	1.33±0.24^{a}	37.06±0.28^{a}
15%	6.37±0.10^{ab}	49.59±0.48^{a}	1.32±0.25^{a}	37.57±0.25^{a}
20%	6.59±0.07^{a}	49.78±0.49^{a}	1.42±0.28^{a}	35.06±0.20^{b}

Values within the same column that are accompanied by distinct letters show a significant difference ($p<0.05$).

The diameter and thickness values of gluten-free crackers changed between 49.13-49.78 mm and 1.32-1.50 mm, respectively (Table 1). There were no notable differences between crackers' diameter and thickness. This revealed that incorporation of defatted sesame meal (up to 20%) does not display a negative impact on the diameter and thickness values of gluten-free crackers. It was also found that when the amount of sesame meal increased from 0% to 10%, spread ratio value increased from 33.92 to 37.06. The increase in spread ratio may be due to the decreasing gluten content as a result of defatted sesame flour addition (Shahzad et al., 2021). Similar findings have been reported for crackers made with composite flour containing defatted sesame flour by Akeem et al. (2023). On the other hand, crackers prepared with 20% sesame meal had a lower spread ratio than crackers made with 10 and 15% sesame meal (Table 1). This result could be attributed to the high protein and fiber content of defatted sesame meal, which could bind to available water and increase viscosity (Giuberti et al., 2018; Melo et al., 2021). The antioxidant properties of gluten-free samples enriched with defatted sesame meal are presented in Table 2. Sesame meal incorporated crackers exhibited a progressive and considerable increase in the phenolic content by

increment of sesame meal level. The presence of phenolic components in sesame meal, mainly lignans, could be responsible for this increase in total phenolic content (Melo et al., 2021).

Table 2. Total phenolic content and antioxidant activity of gluten-free crackers

Crackers	Total phenolic content (mg GAE/100 g)	Antioxidant activity (µmol TE/g)
Control	70.00±0.92^{e}	2.61±0.06^{c}
5%	77.36±0.98^{d}	2.64±0.03^{bc}
10%	96.25±1.13^{c}	2.73±0.04^{abc}
15%	101.61±1.04^{b}	2.82±0.05^{ab}
20%	109.89±0.97^{a}	2.90±0.03^{a}

Values within the same column that are accompanied by distinct letters show a significant difference ($p<0.05$).

The inclusion of defatted sesame meal elicited great results of antioxidant activity in gluten-free crackers, changing from 2.61 to 2.90 µmol TE/g (Table 2). Hafez (2018) found that defatted sesame meal showed high antioxidant activity. The high antioxidant activity of crackers may be associated with lignans in sesame meal, which have antioxidant activity (Sarkis et al., 2014; Shu et al., 2019).
Sensory scores of gluten-free buckwheat crackers are demonstrated in Figure 1. Crackers enriched with 5 and 10% sesame meal elicited similar taste scores to the control. However, higher levels (15 and 20%) of sesame meal decreased taste scores of crackers. On the contrary, increasing level of sesame meal increased odor score of gluten-free crackers. Moreover, gluten-free crackers produced with 10, 15 and 20% sesame meal revealed greater appearance scores than crackers produced with 0 and 5% sesame meal. There were no notable differences between the crispness scores of control and sesame meal-enriched crackers. Regarding the overall acceptability parameter, the enrichment of gluten-free crackers with defatted sesame meal up to 15% revealed similar scores to the control. However, the overall acceptability score of crackers made from 20% sesame meal was lower than the control. Prakash et al. (2018) stated that consumers liked the incorporation of defatted sesame meal up to 50% into biscuit formulation in terms of color, odor, crispiness and taste parameters.

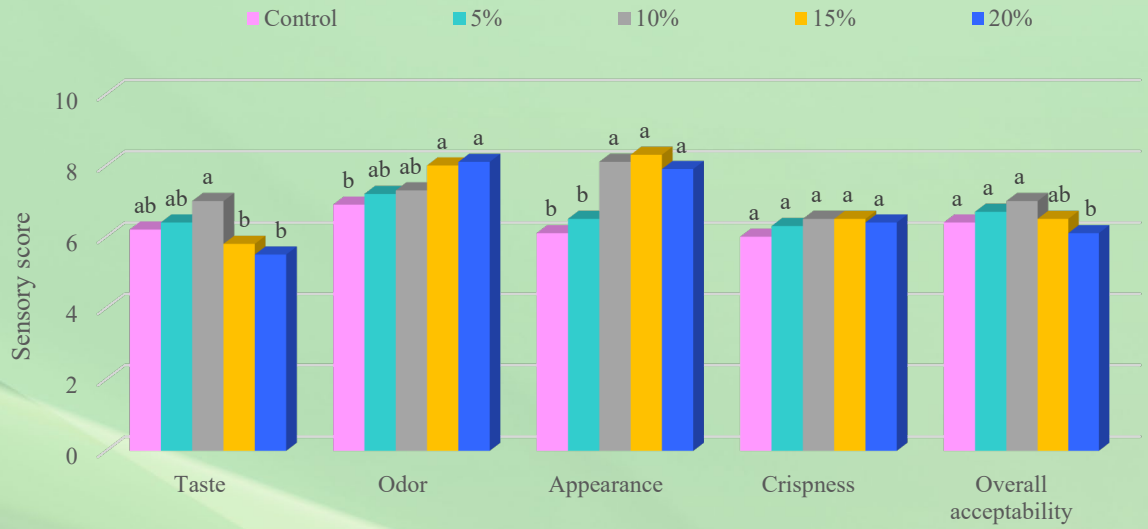


Figure 1. Sensory evaluation of gluten-free crackers

As a conclusion of this study demonstrated that defatted sesame meal (up to 15%) is a good ingredient to improve antioxidant activity of gluten-free crackers as well as acceptable technological and sensory quality. Compared to the control, sesame meal-enriched crackers (up to 15%) revealed a higher spread ratio, stronger antioxidant activity and acceptable sensory quality.

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Advances in Molecular Breeding for Disease Resistance in Banana (Musa Spp): Current Trends and Future Prospects

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Abstract

Banana (*Musa spp.*) is a staple crop providing food security and economic benefits to millions globally. However, its production is severely threatened by biotic and abiotic stresses, including Fusarium wilt, Black Sigatoka, Banana Xanthomonas Wilt, and climate-related challenges. Traditional breeding approaches in banana are hindered by long breeding cycles, polyploidy, and sterility in most cultivated varieties, making genetic improvement challenging. Recent advances in molecular breeding, including marker-assisted selection (MAS), genome-wide association studies (GWAS), and next-generation sequencing, have revolutionized banana improvement by enabling precise trait selection. The application of genetic transformation and CRISPR/Cas9 genome editing has further enhanced the development of disease-resistant and biofortified banana varieties, offering sustainable solutions to production constraints. Despite these advancements, challenges remain in gene introgression, regulatory frameworks, and farmer adoption of genetically improved bananas. Future research should focus on refining genome editing techniques, expanding genomic resources, and integrating artificial intelligence in breeding programs to accelerate cultivar development. This review highlights the progress in molecular banana breeding, discusses existing challenges, and explores emerging opportunities for ensuring banana resilience and productivity in the face of evolving environmental and disease pressures.

Introduction

Banana (*Musa spp.*) is one of the most important staple crops worldwide, serving as a primary source of food, income, and nutrition for over 400 million people, particularly in tropical and subtropical regions (FAO, 2021). Globally, banana production exceeds 155 million metric tons annually, with major producers including India, China, Indonesia, Brazil, and the Philippines (Tripathi *et al*., 2020). In Africa, Uganda, Rwanda, and the Democratic Republic of Congo are among the leading producers, where bananas contribute significantly to food security and livelihoods (Karamura *et al*., 2019). Latin America, particularly Ecuador, Colombia, and Costa Rica, is a major exporter of bananas, supplying global markets, especially in Europe and North America (FAO, 2021).

Challenges in Conventional Banana Breeding

Despite its economic and nutritional importance, banana breeding faces significant challenges. Most cultivated banana varieties, such as the Cavendish and East African Highland bananas, are triploid and sterile, preventing natural recombination and seed-based breeding (Ortiz & Swennen, 2014). Traditional breeding is further hindered by the long reproductive cycle and vegetative propagation, which increases the risk of disease accumulation over successive generations (Perrier *et al*., 2019). The prevalence of devastating diseases, including Fusarium wilt (Tropical Race 4), Black Sigatoka, and Banana Xanthomonas Wilt, further complicates breeding efforts, as resistant cultivars are difficult to develop through conventional methods (Tripathi *et al*., 2020).

Given the limitations of conventional breeding, molecular approaches have emerged as powerful tools for banana improvement. Advances in marker-assisted selection (MAS), genome-wide association studies (GWAS), and genomic selection (GS) have facilitated the identification and introgression of resistance genes, accelerating the breeding process (Ahmadi *et al*., 2021). Additionally, genetic transformation techniques, such as RNA interference (RNAi) and CRISPR/Cas9 genome editing, have enabled targeted modifications for disease resistance and enhanced nutritional content (Tripathi *et al*., 2019). The complete sequencing of the banana genome has provided valuable insights into genetic diversity and trait inheritance, allowing breeders to develop improved cultivars with greater efficiency (D'Hont *et al*., 2012). As climate change and emerging diseases continue to threaten banana production, integrating molecular breeding strategies with conventional methods is essential for ensuring sustainable production and food security.

Genetic and Genomic Advances in Banana

Genome Sequencing of Banana (Musa spp.)

The sequencing of the banana genome has provided critical insights into its genetic diversity, evolutionary history, and potential for breeding improvement. The first draft genome sequence of *Musa acuminata* was published by D'Hont *et al*. (2012), marking a major breakthrough in banana genetics. This sequencing effort revealed that the banana genome is highly complex due to polyploidy and extensive segmental duplications. The reference genome of *Musa acuminata* (AA genome) provided insights into disease resistance genes, stress tolerance pathways, and fruit development mechanisms (D'Hont *et al*., 2012).

Subsequent sequencing efforts focused on the *Musa balbisiana* (BB genome), which contributes to drought tolerance and disease resistance in many cultivated hybrids (Wang *et al*., 2019). More recently, improved genome assemblies have been generated using third-generation sequencing technologies, such as PacBio and Oxford Nanopore, providing higher resolution and facilitating more precise gene annotation (Belser *et al*., 2021). These advancements enable researchers to explore gene-editing strategies and accelerate the development of improved banana cultivars.

Important Genetic Markers (SNPs, SSRs) and Their Applications

Molecular markers play a crucial role in banana breeding by enabling precise selection of desirable traits. Among the most widely used markers are single nucleotide polymorphisms (SNPs) and simple sequence repeats (SSRs).

- **SNP Markers:** SNPs are single-base variations in DNA sequences and are highly abundant in the banana genome. They are widely used in genome-wide association studies (GWAS) and marker-assisted selection (MAS) to identify genes associated with disease resistance and fruit quality (Brown *et al*., 2017). SNP-based genotyping has improved the efficiency of selecting Fusarium wilt-resistant and drought-tolerant banana varieties (Nyine *et al*., 2018).
- **SSR Markers:** SSRs, also known as microsatellites, consist of short, repetitive DNA sequences that are highly polymorphic. They have been extensively used for genetic diversity studies, cultivar fingerprinting, and parentage analysis in bananas (Christelová *et al*., 2017). SSR markers have been instrumental in identifying genetic variability among cultivated and wild banana species, aiding in conservation efforts and pre-breeding programs.

The integration of high-throughput sequencing technologies with SNP arrays and SSR markers has significantly enhanced banana breeding programs. These tools facilitate genomic selection, allowing breeders to predict the performance of hybrids before field trials, thus accelerating the breeding cycle (Perrier *et al*., 2019).

Key Challenges in Banana Breeding

Long Breeding Cycle

Banana breeding programs are hindered by the long reproductive cycle of the plant, which typically spans 2-3 years for the evaluation of hybrids (Ortiz *et al*., 2010). The lack of sexual reproduction in most cultivated banana varieties, which are sterile triploids, further complicates the process, as they must be propagated vegetatively. This extended breeding cycle limits the rate of genetic improvement and slows down the introduction of desirable traits, such as disease resistance and improved yield (Perrier *et al*., 2019). The use of in vitro culture techniques and embryo rescue has partially addressed this issue, enabling faster multiplication of hybrids, but the overall duration remains lengthy compared to other crops (Jain & Swennen, 2010).

Limited Genetic Diversity

The cultivated banana genome is predominantly derived from a narrow gene pool, mainly from *Musa acuminata* and *Musa balbisiana*, which limits the available genetic variation for breeding (Simmonds & Shepherd, 1955). The widespread use of a few cultivars, particularly the Cavendish group, has led to a bottleneck in genetic diversity, making the crop highly vulnerable to diseases and environmental stresses (Nicol *et al*., 2020). Efforts to incorporate wild Musa species into breeding programs have been complicated by incompatibility, sterility, and undesirable traits (Swennen *et al*., 2017). These genetic constraints impede the development of new, resilient banana varieties and pose a significant challenge for long-term production sustainability.

Resistance Breakdown in Improved Varieties

Despite progress in breeding disease-resistant banana varieties, resistance breakdown remains a significant challenge. For example, the Cavendish banana, the most widely grown cultivar globally, is highly susceptible to Fusarium wilt Tropical Race 4 (TR4) (Ploetz, 2015). Initially, the Cavendish was resistant to an earlier strain of Fusarium wilt, but the emergence of TR4 has led to widespread crop losses. Similarly, resistance to Black Sigatoka, a fungal disease, is also subject to breakdown as the pathogen evolves (Alves *et al*., 2020). These challenges highlight the need for continuous genetic improvement and the incorporation of multiple resistance genes to safeguard against evolving pathogens. Integrating stacked resistance genes, genetic diversity, and gene pyramiding approaches are essential to provide durable resistance (Koenig *et al*., 2018).

Table 1. Key Challenges in Banana Breeding

Challenge	Description	Implications	Source
Long Breeding Cycle	Banana breeding takes 2-3 years for hybrid evaluation due to vegetative propagation and long reproductive cycles.	Slows down the introduction of improved traits, limiting genetic progress.	Ortiz & Swennen (2010)
Limited Genetic Diversity	Cultivated bananas mainly come from *Musa acuminata* and *Musa balbisiana*, leading to a narrow genetic pool.	Makes banana crops susceptible to diseases and environmental stresses; limits breeding opportunities.	Simmonds & Shepherd (1955); Perrier et al. (2019)
Resistance Breakdown in Varieties	Disease resistance in improved varieties, such as Cavendish, often breaks down due to evolving pathogens.	Requires continuous breeding to ensure durable resistance to diseases like Fusarium wilt and Black Sigatoka.	Ploetz (2015); Alves et al. (2020)

Molecular Breeding Techniques in Banana

Marker-Assisted Selection (MAS) for Disease Resistance

Marker-Assisted Selection (MAS) is a powerful tool in banana breeding, particularly for disease resistance. MAS relies on genetic markers (such as SNPs, SSRs) associated with resistance traits, allowing breeders to select individuals with desirable traits even before phenotypic expression. For example, MAS has been successfully used in banana breeding for resistance to Fusarium wilt Tropical Race 4 (TR4) and Black Sigatoka (Koenig *et al*., 2018). These diseases are significant threats to banana production worldwide, and MAS accelerates the development of resistant varieties. By incorporating molecular markers linked to these resistance traits, banana breeders can reduce the reliance on field screening, thus shortening the breeding cycle (Brown *et al*., 2017).

MAS has also been applied to select for improved post-harvest quality and drought tolerance in bananas, marking significant progress in improving banana varieties through genetic selection (Perrier *et al*., 2019).

Genome-Wide Association Studies (GWAS) for Trait Mapping

Genome-Wide Association Studies (GWAS) have become a crucial method for identifying genetic loci associated with complex traits in banana. GWAS involves scanning the entire genome for variants that correlate with phenotypic traits, such as disease resistance, yield, and fruit quality. Recent studies have employed GWAS to identify markers linked to resistance to Fusarium wilt, Black Sigatoka, and Banana Bunchy Top Virus (BBTV) (Perrier *et al*., 2019). This technique helps in trait mapping and enables precise genetic selection by pinpointing genes responsible for desirable traits.

By integrating GWAS with high-throughput sequencing technologies, breeders can conduct more efficient genomic selection and improve the precision of their breeding programs (Wang *et al*., 2021). This approach is valuable for enhancing the genetic potential of banana cultivars without relying heavily on traditional breeding methods, thus speeding up the development of superior varieties.

CRISPR/Cas9 Applications in Banana

The CRISPR/Cas9 genome-editing technique has emerged as a revolutionary tool in banana breeding. CRISPR/Cas9 enables precise and targeted modifications of specific genes in the banana genome, allowing for the introduction of beneficial traits without the need for traditional hybridization. This approach has been utilized to develop bananas resistant to Fusarium wilt, a devastating disease that has decimated banana plantations globally (Bortesi *et al*., 2016). By knocking out susceptibility genes or inserting resistance genes, CRISPR/Cas9 has the potential to produce bananas with improved disease resistance and other agronomic traits, such as improved nutritional content and stress tolerance.

Furthermore, CRISPR/Cas9 offers an opportunity for gene functional studies, enabling researchers to explore the role of specific genes in banana growth, development, and resistance mechanisms (Jia *et al*., 2017). While CRISPR/Cas9-based improvements in banana are still in the early stages, its application holds promise for future banana breeding programs.

Genetic Transformation and Transgenic Approaches

Genetic transformation and transgenic approaches have been applied to bananas to introduce specific traits not found naturally within the gene pool. In these approaches, foreign genes are introduced into the banana genome to improve traits such as disease resistance, yield, and nutritional value. For example, bananas have been genetically

engineered to express resistance to Banana Bunchy Top Virus (BBTV) and Fusarium wilt by introducing resistance genes from other plants (Ortiz & Swennen, 2010).

Although transgenic bananas offer significant potential, regulatory and consumer acceptance challenges have hindered the widespread adoption of genetically modified (GM) bananas. However, research into transgenic banana varieties continues, particularly in developing regions where crop loss due to disease is a significant concern. Genetic transformation methods such as Agrobacterium-mediated transformation and biolistic transformation have enabled the successful introduction of foreign genes into banana cultivars (Swennen *et al*., 2013). As regulatory frameworks for GM crops evolve, genetic transformation may become an integral part of banana breeding programs.

Case Studies and Recent Successes

Breeding Programs that Developed Disease-Resistant Bananas

Disease resistance in bananas is critical to ensuring sustainable banana production globally. Several breeding programs have successfully developed disease-resistant cultivars, particularly for Fusarium wilt (Tropical Race 4) and Black Sigatoka, two of the most destructive banana diseases.

Fusarium Wilt Resistance

The International Institute of Tropical Agriculture (IITA) has led efforts to combat Fusarium wilt by using wild Musa species that show natural resistance to the disease. These wild species have been crossed with commercial varieties, and marker-assisted selection (MAS) has been used to identify and select for resistance genes. As a result, the IITA has developed Fusarium-resistant banana varieties, which are undergoing field trials in Uganda and other banana-growing regions. This approach allows the rapid development of resistant cultivars without compromising other desirable traits, such as fruit quality and yield (Ortiz & Swennen, 2010).

Black Sigatoka Resistance

The National Banana Research Program (NBRP) in Ecuador has successfully utilized marker-assisted breeding to develop banana varieties resistant to Black Sigatoka. These banana varieties demonstrate enhanced resistance to the fungal disease, enabling higher productivity with reduced fungicide applications (Perrier *et al*., 2019). The use of molecular markers linked to disease resistance traits has accelerated the process of developing these resistant cultivars.

Biofortification Efforts (e.g., Vitamin A-Enriched Bananas)

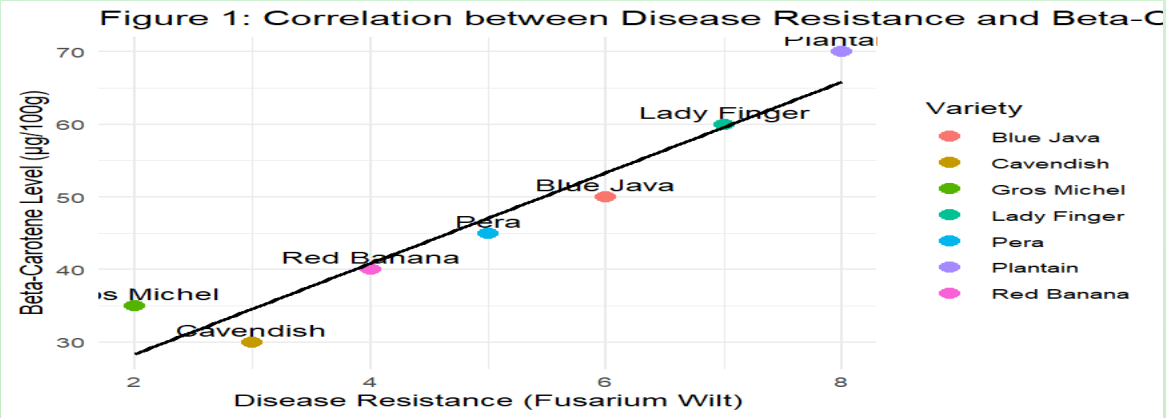
In regions where bananas are a staple crop, enhancing their nutritional content through **biofortification** has become a focus in breeding programs. Biofortified bananas, such as Vitamin A-enriched varieties, are particularly valuable in regions with high levels of Vitamin A deficiency.

Vitamin A-Enriched Bananas in Uganda

In Uganda, a collaborative effort between the International Potato Center (CIP) and the National Agricultural Research Organization (NARO) has led to the development of Vitamin A-enriched bananas. These bananas have been biofortified to contain higher levels of pro-vitamin A carotenoids, primarily beta-carotene, which can be converted to Vitamin A in the body. The bananas developed show up to a 50% increase in beta-carotene content, providing an important tool for tackling Vitamin A deficiency in vulnerable populations. Field trials in Uganda have shown positive results, with farmers expressing interest in these varieties due to their health benefits (Okao *et al*., 2019).

Figure 1 illustrates the relationship between disease resistance (specifically to Fusarium wilt) and beta-carotene levels in various banana varieties, highlighting the ongoing efforts in banana breeding programs. The x-axis represents disease resistance, with higher values corresponding to more resistant varieties, while the y-axis displays beta-carotene content (in micrograms per 100 grams of banana). The plot includes several commonly studied banana varieties, such as Cavendish**,** Pera**,** Red Banana**,** Gros Michel**,** Blue Java**,** Lady Finger**,** and Plantain**.**

The scatter plot shows the distribution of these varieties in terms of their resistance to Fusarium wilt and their beta-carotene levels. The regression line indicates the general trend, and the points represent individual varieties. While certain varieties show a strong correlation between improved disease resistance and higher beta-carotene content, others exhibit a more variable pattern. This data emphasizes the complexity in breeding for both disease resistance and biofortification, key goals in modern banana breeding programs aimed at improving both crop yield stability and nutritional quality."



Source: Okao *et al*.,2029

Future Perspectives and Research Gaps

Banana breeding is at the crossroads of several exciting innovations and challenges that could significantly transform the industry. To meet the growing demands for improved disease resistance, nutritional value, and yield, future research must focus on the integration of cutting-edge technologies, better understanding of the genetic makeup of banana, and improved access to these varieties by smallholder farmers. The following are key future perspectives and research gaps in banana breeding.

Application of AI and Machine Learning in Banana Breeding

The integration of Artificial Intelligence (AI) and machine learning (ML) into banana breeding holds great promise for accelerating genetic improvement. These technologies allow for the analysis of large datasets, including phenotypic, genotypic, and environmental data, to predict the best-performing varieties based on specific traits. AI and ML algorithms can model complex relationships between different traits, enabling predictive breeding that reduces trial-and-error efforts in breeding programs. For instance, AI can help predict disease outbreaks, evaluate genetic diversity, and accelerate the identification of high-yield, disease-resistant varieties. While these technologies have shown great promise in other crops, their application in bananas is still in its early stages, highlighting the need for further development and adaptation to banana-specific breeding programs (Kumar *et al*., 2022).

Enhancing Genome Editing Precision

The advent of genome editing technologies like CRISPR/Cas9 has revolutionized the field of plant breeding, providing the ability to make precise genetic modifications. Genome editing tools have the potential to significantly enhance the disease resistance and nutritional quality of banana varieties, enabling faster development of biofortified and disease-resistant bananas. However, despite significant progress, the precision of genome editing tools needs further refinement to minimize off-target effects and improve the efficiency of genetic modifications. Researchers should also focus on expanding the toolkit to include base editing and prime editing, which offer greater precision in gene modifications (Zhao *et al*., 2021). Additionally, regulatory challenges and public acceptance of genetically modified organisms (GMOs) in banana production need to be addressed to ensure the widespread application of genome editing technologies.

Improving Smallholder Adoption of Improved Varieties

While significant progress has been made in developing improved banana varieties, the adoption of these varieties by smallholder farmers remains a critical challenge. Farmers, particularly in Sub-Saharan Africa and Southeast Asia, often face barriers to accessing improved banana cultivars, including high costs, lack of technical knowledge, and poor infrastructure for seed distribution. Moreover, many smallholder farmers are hesitant to adopt improved varieties due to concerns about market demand, seed availability, and the risk of crop failure. To overcome these barriers, future research should focus on improving seed distribution systems, enhancing farmer education programs, and conducting socio-economic analyses to ensure that improved varieties are economically viable for smallholder farmers. The adoption of community-based breeding programs and farmer-participatory approaches could help increase trust and participation in banana breeding programs (Mubiru *et al*., 2020). Additionally, policies supporting subsidies for seed purchase and post-harvest technologies could help increase adoption rates.

Closing Research Gaps

Despite advances in banana breeding, several research gaps remain. Understanding the genetic mechanisms underlying complex traits, such as disease resistance and drought tolerance, is still limited. More comprehensive genomic studies, particularly in under-researched banana species and cultivars, are required to identify genetic loci

associated with these traits. Furthermore, the banana microbiome plays a crucial role in the plant's health, and future research should explore how microbial communities affect disease resistance and nutrient uptake in bananas (Smith *et al*., 2021). Finally, climate change is expected to alter banana production in many regions, making it imperative to study the potential impacts of climate stressors on banana growth and develop varieties resilient to changing environmental conditions.

Conclusion

Banana breeding has made significant strides in recent years, thanks to advances in molecular tools and technologies. However, challenges such as long breeding cycles, limited genetic diversity, and the need for improved disease resistance continue to pose obstacles for the development of better banana varieties. This review has highlighted the importance of integrating molecular breeding techniques**,** such as marker-assisted selection (MAS)**,** genome-wide association studies (GWAS)**,** and genome editing tools like CRISPR/Cas9, to accelerate banana improvement programs. The application of these tools has not only enabled the development of disease-resistant varieties but has also opened new possibilities for biofortification, such as increasing the levels of beta-carotene and other essential nutrients in bananas..

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Democratization of Crop Irrigation: An Intelligent Approach Combining IoT, Machine Learning, and Social and Solidarity Economy

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Abstract

Equitable access to efficient irrigation remains a major challenge for smallholder farmers, particularly in regions like Morocco, where water access inequalities hinder agricultural productivity and exacerbate socio-economic disparities.
This project proposes an innovative solution to optimize irrigation by combining advanced technologies (IoT and machine learning) with collective governance models and participatory financing based on Islamic finance, aiming to promote sustainable and inclusive water resource management.
The project relies on an IoT platform to collect real-time data on soil moisture and weather conditions, while machine learning algorithms optimize irrigation schedules. A blockchain-based architecture ensures transparency and traceability of transactions, and a participatory financing model, inspired by the social and solidarity economy, promotes the inclusion of smallholders.
This initiative enables more efficient and equitable water management, reducing waste and improving agricultural productivity. It also strengthens trust among stakeholders through blockchain and fosters the socio-economic inclusion of rural communities.
By integrating cutting-edge technologies and collaborative approaches, this project offers a sustainable model for democratizing irrigation, maximizing its socio-economic and environmental impacts. It represents a promising pathway to address water management challenges in vulnerable agricultural regions.

Keywords: *Water democratization, IoT, smart irrigation, machine learning, blockchain, social and solidarity economy, Islamic finance.*

ID: 389

Evaluation of the Reuse of Historical Buildings: The Case of Osmaniye Salih Sefa Yazar Folklore House

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Abstract

The preservation of historical buildings, which convey the socio-cultural characteristics of their respective periods to the present day, is of great importance for the sustainability of cultural heritage. The adaptive reuse of these structures, which have become functionally obsolete due to their inability to meet contemporary needs, is a widely preferred method. This study examines the adaptive reuse of Salih Sefa Yazar Folklore House, one of the few registered buildings in the city center of Osmaniye, where architectural heritage conservation efforts are limited. The study aims to investigate, evaluate, and document the functional and spatial transformations resulting from the adaptation of this significant historical structure.

Originally constructed in the early 1930s by the Askerler family, the building was purchased by the Osmaniye Municipality in 2004. The restoration project was completed in 2009, and the building was reopened as the Salih Sefa Yazar Folklore House. During the restoration process, the original staircase located in the courtyard was relocated inside the house, altering the historical character of the building. Additionally, the structure was damaged in the 2023 Pazarcık earthquake, and its restoration process is currently ongoing, with plans for its future use as a museum. The transformation of the building has been evaluated based on design, participation, and usage criteria. The analyses emphasize the necessity of a holistic approach to the adaptive reuse process.

Key Words: *Historical Building, Adaptive Reuse, Osmaniye Salih Sefa Yazar Folklore House, Design, Utilization.*

ID: 393

Fisheries and Reproductive Biology of European pilchard (Sardina pilchardus (Walbaum, 1792)) in the Southwest of Marmara Sea

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Abstract

European pilchard (*Sardina pilchardus* (Walbaum, 1792)) is one of the most important species in the ecosystem due to its ecological and economic importance. The stocks of this species generally tend to decrease over the years in the Marmara Sea. So, the fisheries and biology of European pilchard were analyzed monthly between January and December 2024 around the Southwest of Marmara Sea, Türkiye. It was determined that European pilchard was caught from commercial fishermen with purse seines using 8-10 mm mesh sizes from September 1st to April 15th and after April 15th with gillnets using 12, 12.5, 12.75, 13 mm mesh sizes in the Marmara Sea. Approximately 10 times more yield was caught per operation with purse seines than with gillnets. The total length and weight varied from 10.0 cm to 15.6 cm (mean:12.42±0.05 cm) and 5.98 g to 26.79 g (mean:13.46±0.18 g) in purse seine, and 10.7 cm to 15.1 cm (mean:12.49±0.05 cm) and 9.62 g to 21.58 g (mean:13.55±0.17 g) in gillnets. The 656 total individuals consisted of 243 females, 217 males, and 196 not dissected. The ratio of males to females was calculated as 1.0:1.12. The total length and weight of all individuals varied from 10.0 cm to 15.6 cm (mean:12.44±0.04 cm) and 5.98 g to 26.79 g (mean:13.48±0.13 g), respectively. The length-weight relationships were determined as $W=0.0091TL^{2.8849}$ in females ($R^2=0.82$), $W=0.0092TL^{2.883}$ ($R^2=0.82$) in males, $W=0.0094TL^{2.8723}$ ($R^2=0.82$) in all sexes. The negative allometric growth was found in females, males and all sexes. The first maturity length was determined as 12.76 cm for females, 11.96 cm for males. The gonadosomatic index value was maximum in February for females and males and minimum in August for females and June for males. The condition factor was maximum in August for females and November for males and minimum in May for females and March for males. The reproductive period of European pilchard takes place between November and April. Consequently, the fisheries and biology of European pilchard should be monitored for its sustainability.

Key Words: *Gillnet, Purse seine, Gonadosomatic index, First maturity length, Reproductive period*

ID: 395

Productivity, Water use efficiency, Soil properties of Sugarcane as influenced by trash mulching and weed management practices under dry season conditions in Nigeria

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Abstract

Productivity, Water use efficiency and Soil properties of Sugarcane were evaluated under dry season conditions. The treatments consisted of two sugarcane genotypes [Bida local and NCS 001], four cane trash mulch rates (0, 3, 6, 9 t ha^{-1}) and four weed management practices [weedy check, five monthly hoe weeding (5 MHW), pre-emergence (PE) application of diuron at 2 kg a.i ha^{-1} + post-emergence (POE) application of 3 – maize force at 179.2 g ha^{-1} (metolachlor 375 g L^{-1} + terbuthylazine 125 g L^{-1} + mesotrione 37.5 g L^{-1}+ 2 MHW, and PE diuron + POE 3-maize force] arranged as a split plot in a Randomized Complete Block Design and replicated three times. Weed management practices and trash mulching were allocated to the main plot, while sugarcane genotypes were the subplot. Reduction in water loss through evapotranspiration and retention of moisture content (41.9 %) was significant with application of 9 t ha^{-1} trash mulch. This invariably sustained the growth of sugarcane and reduced total crop failure during the dry seasons. The cane yield, considered as the most important character of sugarcane, was positively and significantly correlated with sprouting percentage (r=0.531**), number of tillers (r=0.574**), number of millable canes (r=0.716**), sugarcane stalk girth (r=0.595**) and height (r=0.677**), sugarcane brix (r=0.595**), organic carbon (r=0.568**), nitrogen (r=0.532**) and soil moisture content (r=0.531**) while Phosphorus (r=0.445), Potassium (r=0.397), showed positive but non-significant correlation with cane yield. Cane yield was negatively correlated with evapotranspiration (r= -0.500) and weed dry matter (r= -0.556) at all the stages. In order to manage weeds for sustainable growth and increased yield of sugarcane variety, NCS 001 should be used with PE diuron at 2.0 kg a.i ha^{-1} + POE 3-maize force at 2.0 kg a.i ha^{-1} in combination with 6- 9 t ha^{-1} of trash mulch.

Keywords: *Cane trash, Genotypes, Soil properties, Sugarcane, Weed management*

ID: 396

Microalgae as a Feed Source: Market Opportunities and Challenges for Future

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Abstract

Microalgae are increasingly recognized as a valuable feed source, offering diverse applications in food, feed, and high-value products. Their high nutritional value, including proteins, lipids, carbohydrates, vitamins, and minerals, makes them an attractive and sustainable alternative for animal nutrition and aquaculture. Despite these advantages, challenges such as scalable production, economic viability, and regulatory frameworks must be addressed. Current research highlights the potential of microalgae as feed source to enhance animal health and performance, but further development in cultivation, harvesting techniques, and feed formulation for market opportunities and challenges. Optimizing the nutritional composition of microalgae for different species and production stages is crucial for their successful integration. Overcoming these challenges can revolutionize the animal feed industry, providing sustainable and nutrient-rich solutions.

Key Words: *Microalgae, animal feed, food, market*

Introduction

Microalgae have garnered significant attention as a valuable feed source due to their diverse applications in food, feed, and high-value products. These microscopic organisms offer a promising alternative for various industries, including animal nutrition and aquaculture. Studies have highlighted the nutritional benefits of microalgae, showcasing their potential as a sustainable and nutrient-rich feed supplement (Ricigliano, 2020; Yaakob et al., 2014; Souza et al., 2021). Microalgae are rich in proteins, carbohydrates, lipids, vitamins, minerals, and other organic compounds, making them a comprehensive source of essential nutrients for animal feed (Souza et al., 2021).

Despite the numerous advantages of microalgae as a feed source, challenges exist in their widespread adoption. Commercial production of microalgae for food and animal feed is still in its early stages, indicating a need for further research and development to optimize production processes (Dixit et al., 2021). Techno-economic assessments have shown that while microalgae hold potential as a sustainable biomass source, they currently face challenges in competing with market prices for biofuels, animal feed inputs, and bulk chemicals (Dixon & Wilken, 2018). However, with advancements in research and technology, the utilization of microalgae in animal nutrition, aquaculture, and other industries is expected to grow (Ma, 2023; Han et al., 2019).

In Europe, experts have identified significant market opportunities for microalgae, including the production of bioplastics, biofertilizers, nutraceuticals, pharmaceuticals, cosmetics, and biofuels (Rumin et al., 2020). The versatility of microalgae in providing valuable bioproducts and biofuels underscores their potential to contribute to sustainable energy resource development and reduce reliance on fossil fuels (Liber et al., 2020). Moreover, the high nutritional value, rapid growth rates, and low production costs of microalgae make them an attractive alternative to conventional feed sources like fishmeal, particularly in aquaculture (Maizatul et al., 2017).

Nutritional Value of Microalgae As a Feed Source

Microalgae have gained recognition as a valuable and sustainable feed source due to their high nutritional value and diverse applications in various industries, particularly in animal nutrition and aquaculture. These microscopic organisms offer a rich source of essential nutrients such as lipids, proteins, carbohydrates, amino acids, and fatty acids, making them a promising feed supplement for aquaculture-cultivated fish and shrimps (Yaakob et al., 2021). The nutritional content and easy digestibility of microalgae have positioned them as live feed options in the aquaculture industry, contributing to the growth and health of aquatic organisms (Amenorfenyo et al., 2019). Recent studies have demonstrated that microalgae can serve as a comparable protein feed to traditional sources like soya bean meal in livestock and poultry production, highlighting their potential as a sustainable alternative feedstock (Saadaoui et al., 2021).

Microalgae are known for their enriched nutritional profile, containing proteins, lipids, carbohydrates, vitamins, minerals, and antioxidants that are beneficial for animal health (Lopes et al., 2022; Uğuz and Sozcu, 2023, 2024).

The inclusion of microalgae in animal diets has shown improvements in feed utilization, milk production, growth performance, and meat quality in ruminants, underscoring their value as a feed ingredient (Kholif & Olafadehan, 2021). Additionally, microalgae offer essential amino acids, triglycerides, vitamins, and pigments that can enhance the nutritional quality of livestock feed formulations (Ahmad et al., 2022). The high crude protein concentrations and omega-3 fatty acids found in certain microalgae species make them attractive alternative feed resources for animals (Wild et al., 2018). Furthermore, microalgae have been explored as a sustainable source for human food, animal feed, and high-value products due to their high nutritional value and potential benefits since the 1950s (Sui & Vlaeminck, 2018). Their nutritional richness, including proteins, lipids, carbohydrates, and pigments, has positioned microalgae as valuable resources for enhancing the nutrition of food and animal feedstock (Aslam et al., 2017). Studies have also highlighted the benefits of microalgae in fish nutrition, showcasing their potential as a nutrition-rich ingredient for fish feed applications (Annamalai et al., 2021). The nutritional value of microalgae as a feed source is increasingly recognized for its potential to improve animal health, enhance feed formulations, and contribute to sustainable practices in animal nutrition and aquaculture. The diverse array of essential nutrients present in microalgae underscores their significance as a promising feed supplement with broad applications across various industries.

Global Market and Productıon Data of Mıcroalgae Based Feed

The global market for microalgae-based feed is experiencing significant growth and interest due to the nutritional benefits and sustainable nature of microalgae as a feed source. Research has highlighted the potential industrial applications and commercialization of microalgae in the functional food and feed industries, emphasizing the bioactive compounds present in microalgal biomass, such as proteins, polyunsaturated fatty acids, carotenoids, vitamins, and minerals (Camacho et al., 2019). These compounds play crucial roles in functional food and feed products, offering various health benefits, including antioxidant, anti-inflammatory, antimicrobial, and antiviral effects (Camacho et al., 2019).

Microalgae cultivation for feed production at an industrial scale has been demonstrated to be feasible and sustainable, creating opportunities for the utilization of microalgae as alternative feedstocks for livestock and poultry production (Saadaoui et al., 2021). The oil, protein, and antioxidant-rich microalgal biomass are commonly used as feed and food supplements in various forms such as pastes, powders, tablets, capsules, or flakes, designed for daily consumption (Kratzer & Murkovic, 2021). The high protein content of microalgae biomass makes it a valuable resource for aquafeed, animal feed, and poultry feed applications (Sarma et al., 2021).

In the realm of animal nutrition, microalgae have been explored as alternative feedstuffs for pig and poultry feeding, providing a potential substitute for conventional feedstuffs like corn and soybean (Chaves et al., 2021). The use of microalgae in monogastric feeds has shown promise in enhancing feed efficiency and modifying intermediary metabolisms in aquatic animals, underscoring their potential as functional feed additives (Perera et al., 2020). Additionally, microalgae species with high protein concentration and suitable amino acid composition can act as substitutes for conventional protein feeds, while species with high carbohydrate or lipid concentration can offer energy supplementation (Lamminen, 2021).

The global microalgae industry, particularly in China, significantly contributes to the production of microalgae biomass for various applications, with a substantial portion being utilized for human consumption as nutraceuticals and for animal feeds, primarily in marine aquaculture (Chen et al., 2015). The utilization of microalgae biomass as aquafeed is acknowledged as environmentally friendly and cost-effective, further propelling its adoption in the aquaculture sector (Annamalai et al., 2021). The global market for microalgae-based feed is rapidly expanding, driven by the nutritional value, sustainability, and diverse applications of microalgae in animal nutrition and aquaculture. The commercialization and industrial applications of microalgae in functional food and feed industries are paving the way for innovative and sustainable feed solutions that offer health benefits and environmental advantages.

Challenges for Future

The future market challenges of utilizing microalgae as animal feed present a complex landscape that requires addressing various factors to ensure successful integration and adoption. As highlighted in recent research, the potential of microalgae as a sustainable and nutrient-rich feed source is promising, offering benefits such as enhanced animal health, improved feed efficiency, and environmental sustainability (Lum et al. 2013; Aslam et al., 2017). However, several challenges need to be navigated to maximize the utilization of microalgae in animal nutrition.

One of the key challenges facing the future market of microalgae-based animal feed is the need for scalable production methods to meet the increasing demand for feedstock in the livestock and aquaculture industries (Ahmad et al., 2022). While microalgae cultivation has shown potential, there are limitations in scaling up production to commercial levels efficiently and cost-effectively. Addressing issues related to cultivation systems,

nutrient availability, and harvesting techniques is crucial to ensure a reliable and sustainable supply of microalgae biomass for animal feed applications (Ahmad et al., 2022; Hemaiswarya et al., 2010).

Moreover, the economic viability of incorporating microalgae into animal feed formulations poses a significant challenge for market adoption. The cost-effectiveness of producing and processing microalgae biomass for feed applications needs to be optimized to compete with traditional feed sources economically (Zakaria et al., 2020). Techno-economic assessments and research into efficient production methods are essential to overcome cost barriers and make microalgae-based feed competitive in the market (Zakaria et al., 2020; Ahmad et al., 2022).

Another critical aspect that requires attention is the regulatory framework surrounding the use of microalgae in animal feed. As the industry evolves, regulations governing the production, processing, and labeling of microalgae-based feed products need to be established and harmonized to ensure consumer safety and product quality (Novoveská et al., 2019). Clear guidelines and standards will be essential to build trust in microalgae-based feed products and facilitate market acceptance (Novoveská et al., 2019).

Furthermore, research and development efforts are needed to optimize the nutritional composition of microalgae for specific animal species and production stages. Tailoring microalgae strains to meet the dietary requirements of different livestock and aquaculture species can enhance the efficacy of microalgae-based feed formulations and improve animal performance (Cabrita et al., 2022). Understanding the nutritional value and anti-nutritional factors of microalgae species is crucial for formulating balanced and effective feed products (Chen et al., 2022).

Conclusion

In conclusion, while the potential of microalgae as a feed source for animals is promising, addressing challenges related to production scalability, cost-effectiveness, regulatory frameworks, and nutritional optimization is essential for the future market success of microalgae-based animal feed. Its high protein content makes it a valuable resource for animal feed, emphasizing its versatility and nutritional benefits. However, to fully realize these opportunities, several challenges must be addressed:

- Scaling Production: Efficient and cost-effective production methods, along with advancements in cultivation and harvesting, are essential to meet the increasing demand in the livestock and aquaculture industries.
- Economic Viability: Optimizing the economic viability of microalgae-based feed to compete with traditional feed sources is crucial.
- Regulatory Frameworks: Establishing clear regulatory guidelines for production, processing, and labeling is necessary to ensure consumer safety and product quality, thereby building trust and facilitating market acceptance.
- Nutritional Optimization: Research is needed to optimize the nutritional composition of microalgae for different animal species and production stages to enhance feed efficacy and improve animal performance.
- In conclusion, addressing these challenges is essential for the successful integration of microalgae-based feed in animal nutrition. By overcoming these hurdles, microalgae has the potential to revolutionize the animal feed industry, providing sustainable and nutrient-rich solutions for enhanced animal health and performance.

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Türkiye'deki Bazı Patates Çeşit ve Hatlarının Moleküler Karakterizasyonu ve Genetik Çeşitliliği

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Abstract

Bu çalışmada, ticari çeşitlerin ve ıslah hatlarının bulunduğu toplam 168 patates genotipinin moleküler karakterizasyonları yapılmış ve genetik çeşitlilikleri belirlenmiştir. Bu amaçla 10 SSR markörü kullanarak, kapiler elektroforez yöntemiyle genotipleme yapılmış ve Nei genetik mesafe yöntemine göre popülasyon içerisindeki genetik çeşitlilik incelenmiştir. Yapılan genotipleme sonucunda, 10 SSR markörü 168 patates genotipinde toplam 48 skorlanabilir bant oluşturmuştur. Elde edilen 48 banttan 47'si polimorfizm göstermiştir. Kullanılan her bir markörün polimorfik bant sayısı 1 ile 9 arasında değişmiş, ortalama polimorfik bant sayısı 4,7 olarak hesaplanmıştır. Toplam 10 SSR markörünün ortalama polimorfizm oranı ise %95 olarak gerçekleşmiştir. Markörlerin polimorfizm bilgi içeriği (PIC) değeri 0,08 ile 0,42 arasında değişmiş ve ortalama PIC değeri ise 0,28 olarak hesaplanmıştır. İncelenen genotipler içerisinde genetik olarak bir birinden en uzak olanlar, 0,7802 genetik mesafe değerine sahip olan PAE 15-7-19 ile Tiger, PAE 15-6-11 ile Kafkas, PAE 15-7-22 ile Yaprak, PAE 15-7-22 ile Aydos, PAE 15-7-22 ile Yankı, Innovator ile PAE 15-5-8, Nam ile Bettina, Guzine ile PAE 15-5-8 ve Julinka ile Innovator'dür. Birbirine en yakın genotipler 0,0645 genetik mesafe değerine sahip olan Leventbey ile Muratbey ve Bergerac ile Highland B. Red'dir.

Anahtar Kelimeler: *Patates (Solanum tuberosum L.), genetik çeşitlilik, moleküler karakterizasyon, basit dizi tekrarları (SSR)*

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Effects of Different Nitrogen Doses on Quality Criteria of Bread Wheat Varieties

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Abstract

Different nitrogen (0, 4, 8, 12, 16 and 20 kg da-1) fertilizer doses were applied to Pehlivan and Bezostaja-1 bread varieties in a split plot experimental design under Elazığ climate conditions in the 2020-2021 wheat growing season. The aim of the study was to investigate the effects of nitrogen fertilizer doses on grain quality characteristics of bread wheat varieties. In the research, grain quality characteristics such as thousand grain weight, protein, starch, ash, oil, moisture, gluten and fiber ratios of bread wheat varieties were examined. In the study, the differences between the varieties in terms of thousand grain weight and ash content were found to be statistically significant. Other examined characteristics did not create statistical differences among bread wheat varieties. While the Bezostaja-1 variety had a higher value than the Pehlivan variety in thousand grain weight, it was determined that the Pehlivan variety had a higher value in ash ratio. It was determined that the differences between the varieties were not significant in terms of other characteristics examined. The different nitrogen doses applied had a statistically significant positive effect on all the characteristics examined except oil ratio. Among the examined traits, higher values were obtained in 20 kg da-1 nitrogen application for thousand grain weight, ash ratio, moisture ratio values. In terms of protein ratio, starch ratio, gluten ratio and fiber ratio, 16 kg da-1 nitrogen application was considered to be statistically more suitable.

***Key words**: bread wheat, nitrogen doses, quality criteria, thousand grain weight, protein content*

Farklı Azot Dozların Ekmeklik Buğday Çeşitlerinin Kalite Kriterlerine Etkileri

Özet

Farklı azot (0, 4, 8, 12, 16 ve 20 kg da^{-1}) gübre dozları Pehlivan ve Bezostaja-1 ekmeklik çeşitlerine uygulayarak 2020-2021 yılarında buğday yetiştirme sezonunda Elazığ iklim koşullarında bölünmüş parseller deneme deseninde yürütülmüştür. Çalışmada ekmeklik buğday çeşitlerinin tane kalite özeliklerine azot gübre dozlarının etkisinin araştırılması amaçlanmıştır. Araştırmada ekmeklik buğday çeşitlerinin bin tane ağırlığı, protein, nişasta, kül, yağ, nem, glüten ve lif oranlarını gibi tane kalite özellikleri incelenmiştir. Araştırmada incelenen özelliklerden bin tane ağırlığı ve kül oranı yönünden çeşitler arasındaki farklılıklar istatiksel olarak önemli bulunmuştur. İncelenen diğer özellikler ekmeklik buğday çeşitleri arasında istatistiksel farklılıklar oluşturmamıştır. Bin tane ağırlığında Bezostaja-1 çeşidi Pehlivan çeşidinden daha yüksek değere sahip olurken, kül oranında Pehlivan çeşidinin daha yüksek değere sahip olduğu tespit edilmiştir. İncelenen diğer özelikler yönünden çeşitler arasında farklılıkların önemli olmadığı belirlenmiştir. Uygulanan farklı azot dozları incelenen özelliklerden yağ oranı hariç diğer özellikler üzerinde pozitif yönde istatistiksel olarak önemli etkide bulunmuştur. İncelenen özelliklerden bin tane ağırlığı, kül oranı, nem oranı değerleri için 20 kg da^{-1} azot uygulamasında daha yüksek değerler elde edilmiştir. Protein oranı, nişasta oranı, glüten oranı ve lif oranı yönünden 16 kg da-1 azot uygulamasının istatiksel olarak daha uygun olduğu düşünülmüştür.

***Anahtar kelimeler:** ekmeklik buğday, azot dozları, kalite kriterleri, bin tane ağırlığı, protein oranı*

Giriş

Beslenme sorununun çözümü insanlığın hayat mücadelesi olmuştur, önceleri doğada bulduğuyla yetinen insan, sonraları toplayıcılık ve yetiştiricilikle gıda teminini sürdürmüştür. Yerleşik düzene geçilmesiyle bitki yetiştiriciliği yaygınlaşmaya başlamıştır. Her geçen günde bitki yetiştiriciliğindeki yeni teknikler ve uygulamalar verim artışa fırsat yaratmıştır. Dünya üzerinde en fazla ekim alanına sahip olan buğday bitkisi üzerinde yapılan araştırmalarda da süreklilik arz etmektedir. Buğday, dünyada üretim ve tüketim yönünden birinciliğini korumaya devam etmekte ve gelecekte de önceliğini devam ettireceği öngörülmektedir. Tüketici, fırıncı, değirmenci ve üretici buğdayı kullanan zincirin halkasını oluşturmaktadır. Bir buğday tanesi yaklaşık olarak %8-15 oranında protein, %65-75 oranında nişasta, %1.5 oranında yağ, %1-1.5 oranında şeker ve %1-2 oranında kül içermektedir. Tanenin barındırdığı protein, karbonhidrat ve yağ dışında önemli vitaminler de bulunmaktadır (Kün, 1988). Buğday bitkisi kalite kriterlerine göre ekmeklik ve makarnalık olarak gruplandırılmaktadır (Bilgiçli ve Soylu, 2016). Ekmeklik, makarnalık ve bisküvi için üretilen buğdayın özellikleri birbirinden farklı olmaktadır. Ekmeklik

buğdayda kaliteye etki eden en önemli faktör glüten miktarı ve protein oranıdır. Buğdayda kaliteyi belirleyen teknolojik, kimyasal ve fiziksel özellikler üzerinde toprak ve iklim gibi çevre şartları önemli rol oynamaktadır (Dick ve ark. 2016)). Bu sebepten ötürü, yeni geliştirilen çeşit veya hatların kalitesinin tam anlamıyla değerlendirme sağlayabilmesi için farklı çevrelerde yetiştirilmesi gerekmektedir (Karaman ve ark., 2012). Buğdayda kalite kriterleri ekolojik çevre, iklim, toprak özellikleri, sulama, gübreleme gibi uygulamalara etkileşim içindedir (Sobolewska ve ark., 2020). Tüm bitki yetiştiriciliğinde olduğu gibi buğday bitkisi için gübreme verim ve kaliteyi artırıcı bir elementtir. Buğdayda yaprak püskürtme yoluyla azot uygulaması, unların protein içeriğini ve ekmek yapma özelliklerini iyileştirmek için en etkili tarımsal araçlardan biri olarak kabul edilir. Ancak, buğdayın tepkisi gübre formuna, konsantrasyonuna, uygulama sıklığına, büyümeye aşamasına, yaprak yaşı, ayrıca diğer morfolojik ve fizyolojik özellikler bağlıdır (Arif ve ark., 2006; Dick ve ark., 2016). Gübreleme, son yıllarda emtia fiyatlarındaki dramatik artışların ardından, ürün yönetimindeki en pahalı girdilerden biri haline gelmiştir. Buna karşılık, günümüzde ürün yetiştirme sistemleri hem çiftçiler hem de tüm toplum için ekonomik ve çevresel olarak sürdürülebilir olmalıdır. Azot bitki üretimine, çevre ve ekolojiye önemli katkıda bulunmaktadır (Zhang ve ark., 2015). Azot gübresinin orantısız ve zamansız kullanımı sonucunda, düşük N alım, N sızıntısı ve denitrifikasyon oluşmaktadır (Miao ve ark., 2011; Mohsin ve ark., 2012; Wang ve ark., 2022). Topraktaki fazla miktardaki azot kalıntısının yağışla toprak asitlenmesine ve yeraltı suyunun bozulmasına neden olmaktadır (Lu ve ark., 2015). Ayrıca aşırı N gübresi bitki metabolizmasını da etkileyerek nitrat ve nitrit birikmesi sonucunda potansiyel olarak insanlarda zarar oluşturmaktadır (Galloway ve ark., 2008). Bu çalışmada, 0, 4, 8, 12, 16, 20 kg da $^{-1}$ azot dozları Pehlivan ve Bezostaja-1 ekmeklik buğday çeşitlerine Elazığ koşullarında uygulanarak, azot dozlarının kalite özelliklerine etkisinin araştırılması amaçlanmıştır. Araştırma sonucunda elde edilen sonuçlar bölgede buğday tarımı yapan üreticiye katkı sağlaması yönünden önemlidir

Materyal ve Metot

Yürütülen araştırmada Bezostaja-1 ve Pehlivan çeşitler kullanılmıştır. Uygulama faktörü olarak azotun (üre) 0, 4, 8, 12, 16, 20 kg da^{-1} dozları kullanılmıştır. Toprak hazırlığından hemen sonrasında ekimle birlikte 5 kg da^{-1} saf triple süper fosfor gübresi ve azot dozlarının yarısı toprağa karıştırılmıştır. Azot dozunun diğer yarısı bitkinin sapa kalma döneminde uygulanmıştır. Araştırma Elazığ ilinin bağlı Sarılı köyünde 2020 Kasım-2021-Temmuz ayları arasında yürütülmüştür. Tesadüf blokları deneme deseninde 4 tekerrürlü olarak, ana parselde çeşitler alt parselde gübre dozları uygulanmıştır. Tohum ekimleri 20 cm sıra arası mesafesinde 6 sıra ve 3 metre uzunluğunda kurulmuştur. Ekim 31 Ekim 2020 tarihinde elle yapılmıştır. Araştırmanın yürütüldüğü aylara ait bazı iklim özellikleri Çizelge 1. verilmiştir.

Çizelge 1. Denemenin yürütüldüğü dönemde Elazığ iline ait bazı iklim verileri

Aylar	Yıllar	Sıcaklık (C^0)			Ortalama nisbi Nem (%)	Yağış (mm)
		Min.	Max.	Ort.		
Kasım	2020	-3.4	23.2	8.3	66.8	28.8
Aralık	2020	-7.0	12.5	3.7	78.3	16.6
Ocak	2021	-12.1	12.0	1.1	79.2	10.3
Şubat	2021	-9.7	16.8	5.0	59.5	1.0
Mart	2021	-5.9	18.2	6.7	57.4	13.5
Nisan	2021	-1.0	31.1	15.0	44.3	1.8
Mayıs	2021	3.0	36.3	21.1	29.5	1.6
Haziran	2021	10.3	37.3	24.5	26.7	1.7
Temmuz	2021	17.3	42.1	28.9	23.9	0.3

(Anonim, 2024)

Çalışmanın yürütüldüğü Elazığ ili Doğu Anadolu Bölgesi'nin güneybatısında bulunmaktadır. Bölgenin diğer illere göre farklı bir iklim özelliğine sahiptir. Kışlar ise soğuk ve yağışlı, yazlar sıcak ve kurak, karasal iklim görülmektedir. Denemenin yürütüldüğü yetiştirilme sezonunda Kasım ayından Nisan ayına kadar ortalama minimum sıcakların sıfırın alta sürdüğü, Nisan ayından itibaren buğday bitkilerinde gelişmenin başlayabileceği Çizelge 1 anlaşılmaktadır. Nisan ayından itibaren yağış ve nispi nemin çok düşük olduğu görülmektedir. Deneme alanının 0-20 cm derinliğindeki toprak özellikleri; organik madde %1.40, fosfor miktarı 11.47 (kg/da), potasyum miktarı 93.33 (kg/da), kireç oranı %12.20, ve Ph değerinin 7.80 olarak kaydedilmiştir (Anonim, 2019). Araştırmada ekmeklik buğday çeşitlerinin bin tane ağırlığı, protein, nişasta, kül, yan, nem, glüten ve lif oranlarını kapsayan özellikleri incelenmiştir.
İncelenen özeliklere ait veriler JUMP paket programında, bölünmüş parseller deneme planına göre varyans analizi yapılmıştır. Elde edilen ortalamaların karşılaştırılmasında Duncan çoklu karşılaştırma testi uygulanmıştır.

Bulgular ve Tartışma

Elazığ koşullarında iki ekmeklik buğday çeşidine farklı gübre dozları uygulanarak yürütülen çalışma bin tane ağırlığı, protein oranı, nişasta oranına ait elde edilen veriler Çizelge 2'de verilmiştir.

Çizelge 2. Ekmeklik buğday çeşitlerinin farklı azot doz uygulamalarında elde edilen bin tane ağırlığına, protein oranına, nişasta oranına ait ortamalar ve grupları

	Bin tane oranı			Protein oranı			Nişasta oranı		
Gübre dozları	Pehlivan	Bezostaja-1	ortalamalar	Pehlivan	Bezostaja-1	Orta.	Pehlivan	Bezostaja-1	Orta.
0	29.22	32.40	30.81 e	9.67	10.66	10.17 d	58.90	60.20	59.55 d
4	30.68	33.86	32.27 d	13.00	12.45	12.72 c	60.61	62.22	61.41 c
8	31.95	34.76	33.36 c	13.23	13.06	13.15 bc	61.21	62.29	61.75 bc
12	32.70	35.45	34.07 c	14.23	13.80	14.01 ab	61.73	62.47	62.10 bc
16	33.87	36.31	35.09 b	14.71	13.92	14.31 a	64.27	64.68	64.48 a
20	34.67	39.28	36.97 a	15.00	14.13	14.57 a	63.09	63.07	63.08 a
Orta.	32.18 b	35.34 a	33.76	13.31	13.00	13.15	61.64	62.48	62.08

Elazığ koşullarında ekmeklik çeşitlerine farklı azot doz uygulanarak yürütülen çalışmada çeşitlerin istatistiki olarak önemli farklılıklar oluşturduğu kaydedilmiştir. Bezostaja-1 çeşidinde 35.34 g bin tane ağırlığı ile Pehlivan çeşidinden(32.18 g) daha yüksek değere sahip olduğu ve istatiksel olarak farklı grupta yer aldığı kaydedilmiştir. Bin tane ağırlığı yönünden uygulanan 6 farklı azot dozları istatistiksel olarak birbirinden farklı beş grup oluşturmuştur. Bin tane ağırlığı en yüksek 36.97 g ile 20 kg da^{-1} azot doz uygulamasından, en düşük 30.81 g ile 0 kg da^{-1} azot uygulamasından elde edildiği ve farklı gruplarda yer aldığı, diğer uygulamalardan da istatiksel olarak önemli farklılıklar oluşturduğu kaydedilmiştir. Azot doz uygulamasında 8 ve 12 kg da^{-1} uygulamaları sırasıyla 33.36 ve 34.07 g bin tane ağırlıkları ile kendi aralarında istatiksel farklılık oluşturmayıp, diğer uygulamalara arasında farklılıklar oluşturmuştur. Bin tane ağırlığı yönünden çeşit x azot doz interaksiyonu önemsiz bulunmuştur. Çeşit x azot doz interaksiyonunda, en düşük değer 29.22 g ile Pehlivan çeşidinin 0 kg da^{1} azot doz uygulamasında, en yüksek değer ise 39.28 g ile Bezostaja-1 çeşidinin 20 kg azot uygulamasından elde edilmiştir. Diğer çeşit x azot doz interaksiyonlarında bin tane ağırlığı 30.381-36.312 kg arasında değişen değerler göstermiştir (Çizelge 2). Ottman ark. (2000) ABD yapmış olduğu çalışmada çiçeklenmeye yakın azot uygulamanın bin tane ağırlığını sadece birinci yıl arttırdığını, ikinci yılda ise etkilemediğini, Tümsavaş (2001) azotun uygulama zamanının verim unsurları üzerine etkisi olmadığı, farklı azot dozlarının ise verim unsurları üzerinde etkili olduğu, Kaplan (2003) 24 kg dekar azot uygulama zamanının bin tane ağırlığı üzerine etkisinin önemli olduğu bildirmişlerdir. Korkut ve ark (2006) Tekirdağ ekolojik şartlarında bin tane ağırlığının 37.4-50.9 g, Çöl (2007) Konya kuru koşullarında bin tane ağırlığının 26.7-32 g, Mutvali ve ark (2016) Sudan ekolojik 1000 tane ağırlığının 28,7-48,5 g arasında ve özelliklerin bölgeden bölgeye göre değiştiğini, Aksu (2017) buğday çeşitlerine farklı oranlarda gübre dozu uygulamasında bin tane ağılığının 42.23-46.40 g arasında, uygulanan 21 kg da^{-1} azotlu gübre dozunun buğday bitkisine kalite ve verim özellikleri üzerinde olumlu etki ettiğini, Araç ve Topal (2019) Konya ekolojik şartlarında Bezostaja-1 buğday çeşidinin bin tane ağırlığının 53.84 g, Kubar ve ark (2020) Çin'de beş farklı azot dozunun farklı zamanlarda yapılan uygulamalarda bin tane ağırlığının 19-43 g, Zheng ve ark(2021) Çin'de iki buğday, bin tane ağırlığının 35-38 g, olduğunu bildirmişlerdir. Zhao ve ark. (2023) azot kullanım arttırılmasının, buğday ıslahında dengeli ve yüksek verim ve kaliteye ulaşmak için en etkili yöntemlerden birinin olduğunu söylemişlerdir. Buğday ile ilgili yapılan araştırmalarda, farklı genotiplerin kullanılan azot kullanım etkinliğinin, tane ağırlığında önemli olduğu bildirmişlerdir. Daha önceki araştırmalardan da anlaşıldığı gibi azot dozunun uygulama zamanına, ekolojiye çeşit göre farklılıklar göstereceği belirtilmektedir.

Ekmeklik buğday çeşitleri ile yürütüle çalışmada protein oranı yönünden çeşitler arasında istatistiki önemli farklılık görülmemiştir. Bezostaja-1 ekmeklik buğday çeşidi % 13.00 ve Pehlivan çeşidinin de %13.31 protein oranı sahip olduğu belirlenmiştir. Uygulanan farklı azot dozlarına göre protein oranları yönünden birbirinden farklı istatiksel olarak üç grup ve iki geçiş grubu oluşturmuştur. Protein oranı en yüksek 20 kg da^{-1} azot uygulamasında % 14.57 olduğu, onu ikinci sırada % 14.31 oranıyla takip eden 16 kg da^{-1} azot doz uygulamanın, üçüncü sırada 12 kg da^{-1} uygulamasının % 14.01 ile geçiş grubuyla izlediği ve kendi aralarında istatiksel olarak önemli farklılıklar oluşturmadığı kaydedilmiştir. En düşük protein oranı % 10.17 ile kontrol uygulamasından elde edildiği ve diğer azot doz uygulamalarından istatiksel önemli derecede farklılık olduğu belirlenmiştir. Onu ikinci sırada 4 kg da azot uygulamasının %12.72 protein oranıyla izlediği, geçiş grubunda yer alan 8 kg da^{-1} azot uygulaması hariç diğer azot doz uygulamalarından istatiksel olarak önemli farklılıklar oluşturduğu kaydedilmiştir. Protein oranı yönünden çeşit x azot doz interaksiyonu önemsiz bulunmuştur. Çeşit x azot doz interaksiyonunda, en yüksek protein oranı % 15.00 ile Pehlivan 20 kg da^{1} uygulamasında, en düşük değer ise % 9.67 ile Pehlivan çeşidinin 0 kg da^{1} azot uygulamasından elde edilmiştir. Diğer çeşit x azot doz interaksiyonlarında protein oranı % 10.660 – 14.715 arasında değişen değerler göstermiştir (Çizelge 2.). Yürütülen önceki çalışmalarda Ottman ark. (2000) ABD yapmış olduğu çalışmada çiçeklenmeye yakın azot uygulamanın tanedeki protein oranını arttırdığı sadece birinci

yıl arttırdığını, ikinci yılda ise etkilemediğini vurgulamıştır. Soylu ve Sade (2006) iki yıllık makarnalık buğdayla yaptıkları çalışmada, kontrol uygulamalarında protein oranlarının yıllara göre %10.37 ve %11.11, azottun 20 kg da^{-1} uygulamasında protein oranının %13.94 ve %14.73 olduğu, azotun tamamının ekimde uygulanmış olan parsellerde %11.82 ve %12.67, azotun üç parça şeklinde uygulanmış parsellerde %12.68 ve % 13.52 olduğunu belirtmişlerdir. Protein oranının Yağdı (2004) % 11.85-13.44, Aydın ark. (2007) % 12.4-13.3, Menderis (2006) % 12.49-14.92, arasında değişim gösterdiğini bildirmişlerdir. Çağlar ve ark (2006) 25 farklı ekmeklik buğdayın Erzurum ekolojisine protein oranının ise %11.2-13.5, Çöl (2007) Konya kuru koşullarında protein oranının %8.7-11.6, Korkut ve ark (2006) Tekirdağ ekolojik şartlarında protein içeriğinin %11.9-%13.7, Tunca (2012) ülkemizde yaygın yetiştirilen 16 kışlık ekmeklik buğday çeşidinin protein oranının %9.7-13.9 arasında değişim gösterdiği açıklamıştır. Mutwali ve ark (2016) Sudan ekolojisine yürüttükleri çalışmada protein oranını %9,96-14,06 olduğu, genotipler ve lokasyonlar arasında önemli farklılıkların olduğu, özelliklerin bölgeden bölgeye göre değiştiği, Aksu (2017) buğday çeşitlerine farklı oranlarda gübre dozu uygulamasında protein oranının %11.43-15.80 olduğu, 21 kg da^{-1} azotlu gübre dozunun buğday bitkisinin kalite ve verim özellikleri üzerinde olumlu etkide bulunduğunu bildirmişlerdir. Zhao ve ark. (2023) azot kullanım arttırılmasının, buğday ıslahında dengeli ve yüksek verim ve kaliteye ulaşmak için en etkili yöntemlerden birinin olduğunu ifade etmişlerdir. Daha önceki buğday ile ilgili yapılan araştırmalarda, farklı genotiplerin azot kullanım etkinliğinin, farklı çevreye ve kullanılan faktörlere göre değiştiği ve tane protein oranında etkili olduğunu belirtmişlerdir.

İncelenen özelliklerden nişasta oranın ekmeklik buğday çeşitleri arasında istatistiki farklılığın olmadığı kaydedilmiştir. Pehlivan çeşidinde % 61.64, Bezostaja-1 çeşidinde % 62.48 nişasta oranı tespit edilmiştir. Farklı azot uygulamaları nişasta oranını yönünden birbirinden farklı üç (a, c, d) ve birde (bc,) geçiş grubu oluşturmuştur. Araştırmada kullanılan ekmeklik buğday tanelerinde en yüksek nişasta oranı % 64.48 ile 16 kg da^{-1} azot doz uygulamasından elde edildiği, onu ikinci sırada izleyen %63.08 ile 20 kg da^{-1} azot uygulaması hariç ve diğer uygulamalardan istatiksel olarak önemli derecede farklılık oluşturduğu görülmüştür. En az nişasta oranı % 59.55 ile 0 kg da^{-1} azot doz uygulamasından elde edildiği ve diğer uygulamalardan istatiksel olarak önemli derecede farklılık oluşturduğu kaydedilmiştir. Onu ikinci sırada %61.41 nişasta oranıyla izleyen 4 kg da^{-1} azot uygulamasının, 8 ve 12 kg da^{-1} azot dozları uygulamaları haricinde diğer uygulamalardan istatiksel olarak önemli derecede farklılık oluşturduğu tespit edilmiştir. Çeşit x azot doz uygulama interaksiyonlarında nişasta oranı en yüksek % 64.682 ile Bezostaja çeşidinde 16 kg da^{-1} azot uygulamasından, en düşük nişasta oranı % 58.90 ile Pehlivan çeşidinin kontrol uygulamasında kaydedilmiştir. Değer intereaksiyon uygulamalarında nişasta oranı %60.61-64.27 arasında değişim göstermiştir (Çizelge 2.). Yaraşır (2018) Buğday bitkisine uygulanan beş farklı dozlarda (0, 1, 2, 3, 4 t da^{-1}) sıvı biyogaz atıkları ile üç farklı (0, 9, 18 kg da^{-1}) mineral azot dozu etkisinin incelendiği çalışmada nişasta oranını % 51.03 - 56.90 arasında değiştiğini belirtmiştir. Kubar ve ark. (2021), Çin'de buğday bitkisine 7.5, 15, 22.5 30 kg da-1 azot gübre uygulamasında, buğdayın kalite kriterlerine yalnızca N oranından değil aynı zamanda N uygulama zamanlarının da etkili olduğu belirtilmiştir. Yürütülen araştırmada da nişasta oranını azat dozlarının etkilediği görülmüştür. Genetiğe ek olarak, çevresel faktörler buğday verimi ve bileşimiyle ilgili değişkenliğin yaklaşık üçte ikisine katkıda bulunmaktadır (Hellemans ve ark., 2018)

Ekmeklik buğday çeşitlerinin farklı azot doz uygulamalarında elde edilen kül, yağ nem oranlarına ait ortamalar ve grupları Çizelge 3 verilmektedir.

Çizelge 3. Ekmeklik buğday çeşitlerinin farklı azot doz uygulamalarında elde edilen kül, yağ nem oranlarına ait ortamalar ve grupları

	Kül oranı			Yağ oranı			Nem oranı		
Gübre dozları	Pehlivan	Bezostaja-1	Ortalamalar	Pehlivan	Bezostaja-1	Orta.	Pehlivan	Bezostaja-1	Orta.
0	0.81	0.55	0.68 e	1.00	0.90	0.95	8.35	8.15	8.25 d
4	1.06	0.64	0.85 d	1.13	0.90	1.01	8.42	8.30	8.36 cd
8	1.27	1.03	1.15 c	1.19	1.03	1.11	8.53	8.39	8.46 bc
12	1.35	1.21	1.28 bc	1.20	1.04	1.12	8.48	8.42	8.45 bc
16	1.45	1.24	1.35 bc	1.20	1.14	1.17	8.56	8.47	8.51 b
20	1.57	1.29	1.43 a	1.24	1.18	1.21	8.72	8.61	8.66 a
Orta.	1.25 a	0.99 b	1.12	1.16	1.03	1.09	8.51	8.39	8.45

Araştırmada kullanılan iki ekmeklik buğday çeşidinin kül oranının önemli farklılıklar oluşturduğu ve iki grup oluştuğu gözlemlenmiştir. Ekmeklik buğday çeşitlerinin kül oranları Pehlivan çeşidinde % 1.25, Bezostaja-1 çeşidinde % 0.99 olduğu ve istatistiki olarak farklı grupta yer aldığı Çizelge 4.3'de görülmektedir. Farklı azot uygulamalarında ekmeklik buğday çeşitlerinin kül oranının % 0.68 - 1.43 arasında değişim gösterdiği ve kendi aralarından birbirinden farklı 4 grup ve birde geçiş grubu oluşturduğu kaydedilmiştir. En yüksek kül oranı % 1.43 ile 20 kg da^{1} azot dozunda elde edildiği ve diğer azot dozları uygulamalarından istatiksel olarak önemli farklılık oluşturduğu kaydedilmiştir. En düşük kül oranı % 0.68 ile 0 kg da^{-1} azot dozunda elde edilmiş ve diğerlerinden istatiksel olarak önemli farklılık oluşturduğu tespit edilmiştir. Azot doz uygulamasında 12 ve 16 kg da^{-1} uygulamasında kül oranları sırasıyla % 1.28, 1.35 değerleriyle aynı geçiş grubunda yer aldığı 8 kg da^{-1} azot doz

uygulaması hariç diğer azot dozları uygulamalarından istatiksel olarak farklılıklar oluşturduğu belirlenmiştir. Çeşit azat doz uygulama interaksiyonlarında ise kül oranı en yüksek % 1.57 ile Pehlivan çeşidinin 20 kg/da^{1} azot dozu uygulamasından, en düşük kül oranı % 0.552 ile Bezostaja-1 çeşidinin kontrol uygulamasından elde edilmiştir. Diğer interaksiyon uygulamalarında kül oranlarının % 1.457 -0.645 arasında değişim gösterdiği kaydedilmiştir (Çizelge 3.). Ünal (2003), buğdayda un ve kalitesinin belirlenmesi amacıyla yapmış olduğu çalışma sonucunda; unun barındırmış olduğu inorganik maddeler 'kül' olarak adlandırılmaktadır. Bu inorganik maddeler buğdayın kabuğunda %12-20 oranında olduğu sonucunu bildirmiştir. Yaraşır (2018) Buğday bitkisine uygulanan beş farklı dozlarda (0, 1, 2, 3, 4 t da^{-1}) sıvı biyogaz atıkları ile üç farklı (0, 9, 18 kg da^{-1}) mineral azot dozu etkisinin incelendiği çalışmada kül oranları % 1.22 - 1.51 arasında değiştiğini belirtmiştir.

Yürütülen çalışmada incelenen özelliklerden yağ oranı Pehlivan çeşidinde %1.161, Bezostaja-1 çeşidinde % 1.035, olduğu ve istatistiksel farklılığın oluşmadığı tespit edilmiştir. Uygulanan azot dozlarının incelenen yağ oranı üzerinde istatistiki olarak önemli farklılık oluşturmadığı görülmüştür. Farklı azot uygulamalarında en yüksek yağ oranı % 1.21 ile 20 kg da^{-1} azot dozundan, en düşük yağ oranı % 0.95 ile 0 kg da^{-1} azot doz uygulamasından elde edildiği kaydedilmiştir. Diğer azot doz uygulamalarında yağ oranı % 1.01 - 1.17 arasında değişim göstermiştir. Çeşit x azot doz uygulama interaksiyonlarında yağ oranı en yüksek% 1.24 ile Pehlivan çeşidinin 20 kg da^{1} azot dozu uygulamasında, en düşük % 0.90 ile Bezostaja-1 çeşidinin kontrol uygulamasında gerçekleştiği belirlenmiştir. Diğer interaksiyon uygulamalarında yağ oranlarının % 1.20-1.0 arasında değişim gösterdiği tespit edilmiştir (Çizelge 3.). Yaraşır (2018) Buğday bitkisine uygulanan beş farklı dozlarda (0, 1, 2, 3, 4 t da^{-1}) sıvı biyogaz atıkları ile üç farklı (0, 9, 18 kg da^{-1}) mineral azot dozu etkisinin incelendiği çalışmada yağ oranları % 1.94 -2.35 arasında değiştiğini tespit etmiştir. Kubar ve ark. (2021), Çin'de buday bitkisine 7.5, 15, 22.5 30 kg da-1 azot gübre uygulamasında, buğdayın kalite kriterlerine yalnızca N oranından değil aynı zamanda N uygulama zamanlarının da etkili olduğu belirtilmiştir.

Araştırmada incelenen özelliklerden nem oranının iki ekmeklik buğday çeşitleri arasında istatiksel farklılıkların oluşturmadığı, Pehlivan çeşidinin % 8.72 Bezostaja-1 çeşidinin % 8.61 nem oranına sahip olduğu gözlemlenmiştir. Farklı azot uygulamaları nem oranlarına göre istatiksel olarak üç grup ve ikide geçiş grubu oluşturduğu belirlenmiştir. En yüksek nem oranı % 8.66 ile 20 kg da^{-1} azot doz uygulamasında elde edildiği ve diğer azot doz uygulamalarından istatiksel olarak önemli farklılıklar oluşturduğu kaydedilmiştir. En düşük nem oranı % 8.25 ile kontrol uygulamasından elde edildiği, onu ikinci sırada % 8.36 ile 4 kg da^{-1} azot doz uygulaması hariç diğer azot doz uygulamalarından istatiksel olarak önemli farklılıklar oluşturduğu belirlenmiştir. Azot doz uygulamalarından 8 ve 12 kg da^{-1} uygulaması nem oranı yönünden aynı geçiş grubunda yer aldığı, 4 ve 16 kg da^{-1} doz uygulaması hariç diğer uygulamalardan istatistiki olarak önemli farklılık oluşturduğu tespit edilmiştir. Çeşit x azot doz uygulama interaksiyonlarında nem oranı en yüksek % 8.72 ile Pehlivan çeşidinde 20 kg da^{1} azot dozu uygulamasından, en düşük nem % 8.15 ile Bezostaja çeşidinden elde edilmiştir. Diğer interaksiyonlarda ise nem değerleri % 8.30 – 8.61 arasında değişim gösterdiği ve istatistiksek farklılıkların oluşmadığı kaydedilmiştir (Çizelge 3.). Ünal (2003) ülkemizde yetiştirilen ekmeklik buğday çeşitlerinin nem içeriklerinin % 8-14 arasında, ortalama % 9-11 oranında olduğunu belirtmiştir. Tayyar, (2005) Çanakkale'de yürüttüğü çalışmada 8 hat ve 26 çeşit olmak üzere 34 genotip materyal nem oranlarının %11.7-12.4 arasında değiştiğini tespit etmişlerdir. Tahıl tanesindeki nem oranın da genetik faktörlerden daha çok bitkinin yetiştiği çevresel faktörlerinin etkisi bulunmaktadır, yürütülen çalışmada gübre dozlarındaki farklılık bu durumu açıklamaktadır.

Ekmeklik buğday çeşitlerinin farklı azot doz uygulamalarında elde edilen glüten ve lif oranlarına ait ortamalar ve grupları Çizelge 4'de verilmiştir.

Çizelge 4. Ekmeklik buğday çeşitlerinin farklı azot doz uygulamalarında elde edilen glüten ve lif oranlarına ait ortamalar ve grupları

	Glüten oranı			Lif oranı		
Gübre dozları	Pehlivan	Bezostaja-1	ortalamalar	Pehlivan	Bezostaja-1	Orta.
0	36.55	37.10	36.82 d	3.95	3.63	3.79 d
4	40.37	43.67	42.02 c	4.08	4.08	4.08 c
8	41.95	44.80	43.37 bc	4.56	4.27	4.41 b
12	44.82	46.50	45.66 ab	4.72	4.43	4.58 b
16	45.50	48.00	46.75 a	4.97	4.62	4.80 a
20	46.32	47.57	46.95 a	5.16	4.79	4.98 a
Orta.	42.58	44.60	43.59	4.57	4.30	4.44

Yürütülen çalışmada glüten oranının iki ekmeklik buğday çeşitleri arasında istatiksel farklılıkların oluşturmadığı, Pehlivan çeşidinin % 42.58, Bezostaja-1 çeşidinin % 44.60 glüten oranına sahip olduğu tespit edilmiştir. Farklı azot uygulamaları glüten oranlarına göre istatiksel olarak üç grup(a, c, d) ve ikide (ab, bc) geçiş grubu oluşturmuştur. En yüksek glüten oranı % 46.95 ile 20 kg da^{-1} ve %46.75 ile 16 kg da^{-1} azot doz uygulamasından elde edildiği belirlenmiştir. Glüten oranları yönünden 20, 16, 12 kg da-1 azot doz uygulamaları arasında istatiksel farklılığın olmadığı, diğer azot doz uygulamaları arasında istatiksel olarak önemli farklılıkların olduğu

kaydedilmiştir. En düşük glüten oranı % 36.82 ile 0 kg da^{-1} azot doz uygulamasından elde edildiği ve diğer azot doz uygulamalarından istatiksel olarak önemli farklılıklar oluşturduğu belirlenmiştir. Azot doz uygulamalarından 8 ve 12 kg da^{-1} uygulaması glüten oranı yönünden geçiş gruplarında yer almıştır. Glüten oranı yönünden ikinci düşük değer %42.02 ile 4 kg da^{-1} azot doz uygulamasından elde edildiği, 8 kg da^{-1} azot doz uygulaması hariç, diğer azot gübre uygulamalarından istatiksel olarak önemli farklılıklar kaydedilmiştir. Glüten oranı yönünden çeşit x azot doz uygulama interaksiyonlarında en yüksek % 48.00 ile Bezostaja-1 çeşidinin 16 kg da^{1} azot dozu uygulamasından, en düşük % 36.55 ile Pehlivan çeşidinin kontrol uygulamasında elde edilmiştir. Diğer interaksiyonlarda ise glüten oranlatı % 47.57-37.10 arasında değişim göstermiş ve istatistiksek farklılıkların oluşmadığı kaydedilmiştir (Çizelge 4.28). Glüten oranı, un kalitesinin saptanmasındaki en önemli özelliklerden biri olduğu, düşük oranda glüten barındıran buğdaylarda % 20'den az, orta derecedeki buğdaylarda % 20-27 arasında, iyi özellikteki buğdaylarda % 28- 35 arasında, yüksek glüten oranına sahip buğdaylarda ise oranın % 35'ten yukarı olduğu bildirilmektedir (Ünal, 2003). Tayyar, (2005) Çanakkale'de yürüttüğü çalışmada 8 hat ve 26 çeşit olmak üzere 34 genotip materyallerinde glüten değerlerinin 42.5-30.5 g, Kahrıman (2007) Çanakkale şartlarında yürütülen çalışmada glüten miktarının %25.3-43.6 arasında değişim gösterdiğini tespit etmişlerdir. Daha önceki yürütülen çalışmalarda elde edilen sonuçlardan görüldüğü gibi glüten oranının çeşittin genetik yapısının yanı sıra çevresel ve iklim faktörlerinde de etkilendiği anlaşılmaktadır.

Araştırmada incelenen özelliklerden ham lif oranının iki ekmeklik buğday çeşitleri arasında istatiksel farklılıkların oluşturmadığı, Pehlivan çeşidinin % 4.57 Bezostaja-1 çeşidinin % 4.30 ham lif oranına sahip olduğu gözlemlenmiştir. Farklı azot uygulamaları ham lif oranlarına göre istatiksel olarak dört grup oluşturmuştur. En yüksek ham lif oranı sırasıyla % 4.98, 4.80 ile 20 ve 16 kg da^{-1} azot doz uygulamasıyla aynı grupta yer aldığı ve diğer azot doz uygulamalarından istatiksel olarak önemli farklılıklar oluşturduğu kaydedilmiştir. En düşük ham lif oranı % 3.79 ile kontrol uygulamasından elde edildiği ve diğer azot doz uygulamalarından istatiksel olarak önemli farklılıklar oluşturduğu belirlenmiştir. Ham lif oranı yönünden ikinci düşük değer %4.08 ile 4 kg da^{-1} azot doz uygulamasından elde edildiği ve istatiksel olarak diğerlerinden farklı grupta yer aldığı tespit edilmiştir. Azot doz uygulamalarından 8 ve 12 kg da^{-1} uygulaması ham lif oranı yönünden aynı grubu oluşturarak, diğer azot uygulamalarından istatistiki olarak önemli farklılık oluşturduğu kaydedilmiştir. Çeşit x azot doz uygulama interaksiyonlarında ham lif oranı en yüksek % 5.16 ile Pehlivan çeşidinde 20 kg da^{1} azot dozu uygulamasından, en düşük nem % 3.63 ile Bezostaja-1 çeşidinden elde edilmiştir. Diğer interaksiyonlarda ise ham lif değerleri % 4.97-3.95 arasında değişim gösterdiği ve istatistiksek farklılıkların oluşmadığı kaydedilmiştir (Çizelge 30). Kubar ve ark. (2021), Çin'de buğday bitkisine 7.5, 15, 22.5 30 kg da^{-1} azot gübre uygulamasında, buğdayın kalite kriterlerine yalnızca N oranından değil aynı zamanda N uygulama zamanlarının da etkili olduğu belirtilmiştir. Yaraşır (2018) Buğday bitkisine uygulanan beş farklı dozlarda (0, 1, 2, 3, 4 t da^{-1}) sıvı biyogaz atıkları ile üç farklı (0, 9, 18 kg da^{-1}) mineral azot dozu etkisinin incelendiği çalışmada lif oranları % 2.87 - 3.29 arasında değiştiğini kaydetmiştir. Yürütülen çalışmada ham lif oranı üzerine azot dozlarının etkili olması çevresel faktörlerin etkili olduğunu ifade etmektedir.

Sonuç

Ekmeklik buğday çeşitleri olarak Elazığ bölgesinde üretimi yapılan Pehlivan ve Bezostaja-1 çeşitlerine farklı (0, 4, 8, 12, 16 ve 20 kg da^{-1}) azot gübre dozları uygulayarak yürütülen çalışmada bin tane ağırlığı, protein, nişasta, kül, yağ, nem, glüten ve lif oranlarını incelenmiştir. Yürütülen çalışmada Bezostaja-1 çeşidinin diğer Pehlivan çeşidinden daha yüksek bin tane ağırlığına sahip olduğu, kül oranı yönünden Pehlivan çeşidinin daha yüksek değere sahip olduğu kaydedilmiştir. İncelenen diğer özelikler yönünden çeşitler arasında farklılıkların önemli olmadığı belirlenmiştir. Araştırmada kullanılan ekmeklik buğday çeşitlerinin tane kalite kriterlerinden bin tane ağırlığı, protein, nişasta, kül, nem, glüten ve lif oranlarını üzerine uygulanan gübre dozlarının olumlu etkide bulunduğu kaydedilmiştir. Çalışmanın daha sonraki çalışmalara kaynak oluşturacağı ve daha kararlı sonuç elde edilmesi için gübre denemesinin tekrarlanması uygun görülmüştür.

Araştırmacıların Katkı Oranı Beyan
Makalede yazarlar eşit oranda katkı hakkına sahiptir.

Çıkar Çatışması Beyanı
Makale yazarları aralarında herhangi bir çıkar çatışması bulunmamaktadır.

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Effects of Relationships Between Leaf Area Value Removed and Cob Characteristics in Corn Plants

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Abstract

The corn plant completes its development in a very short time, the major organs contributing to the yield of the corn plant are the roots and leaves. The aim of this study was to examine the leaf areas, ear grain weights, cob weights, ear row numbers, and grain numbers of ear row by applying four different leaf removal treatments to D. 6761, P. 1921, P. 2105 and Klumet hybrid corn varieties and to determine the correlation relationship between the examined traits. It was observed that the leaf areas increased from the top tassel to the leaves above the ear, but the three leaves below the top tassel contributed more to the ear grain yield than the three leaves above the ear. It was recorded that all leaves above the ear contribute to the yield, and that there is a linear relationship between ear grain yield and leaf area and cob diameter. The effect of leaf removal practices on the number of ear rows and the number of grains per row is thought to be less effective than genetic factors.

Key words: *maize varieties, leaf removal, leaf area, grain weight, principal components analysis.*

Mısır Bitkisinde Yaprak Uzaklaştırmanın Koçan Özelliklerine Etkisi

Özet

Yetişme süresini çok kısa sürede tamamlayan mısır bitkisinin verimine katkıda bulunmada, büyük öncülük eden organları kök ve yapraklarıdır. Bu çalışmada, D. 6761, P. 1921, P. 2105 ve Klumet hibrid mısır çeşitlerinde dört farklı yaprak alma işlemi uygulanarak, çeşitlerin yaprak alanları, koçan tane ağırlıkları, somak ağırlıkları, koçanda sıra sayıları, sırada tane sayılarının incelenmisi ve incelenen özellikler arasındaki corelasyon ilişkisinin belirlenmesi amaçlanmıştır. Yaprak alanlarının tepe püskülünden koçan yukarısındaki yapraklar inildikçe artığı, fakat tepe püskülünün altındaki üç yaprağın koçanın üstündeki üç yapraktan daha fazla koçan tane verimine katkı sağladığı görülmüştür. Koçanın yukarısındaki tüm yaprakların verime katkısının olduğu, koçan tane verimi ile yaprak alanı ve somak çapı arasında doğrusal ilişki olduğu kaydedilmiştir. Koçan sıra sayısı ve sırada tane sayısı üzerine yaprak alma uygulamalarının etkisinin genetik faktörlerden daha az etkili olacağı sonucuna varılmıştır.

Anahtar kelimeler: *mısır çeşitleri, yaprak alma, yaprak alanı, tane ağırlığı, temel bileşenler analizi.*

Giriş

Bitkilerde verimi etkileyen faktörler arasında hücre fizyolojisi, yaprak alanı, yaprak şekli gibi morfolojik özellikler, su, ışık, sıcaklık, karbondioksit ve bitki besin maddeleri gibi çevresel faktörlerin yanı sıra asimilasyon hızı ve üretilen asimilat miktarı da yer almaktadır. (Li et al., 2021; Reddy et al., 2010). Bitkilerde güneş ışığının büyük bir kısmı yaprak ayası tarafından tutulmaktadır. Bu sebeple yaprak yüzeyi diğer bitkilere oranla yaprakları geniş olan mısır bitkisinin fotosentez ile enerji üretme faaliyeti oldukça yüksek olmaktadır (Yue et. al. 2021). Tohumların, sapların ve köklerin canlılıklarını devam ettirebilmek için gerek duydukları besin maddeleri yapraklardan taşınmaktadır. Yapraklar bitkinin diğer fotosentez yapan organlarından ekonomik öneme sahip koçana besin maddesinin taşınmasında, birçok bitkide olduğu gibi mısırda da verimi etkilemektedir (Aldrich ark., 1982). C4 bitkisi olduğu bilinen mısır bitkisi, güneşi ve suyu en iyi değerlendiren ve bu yüzden yüksek verim verebilen bir bitkidir. Özellikle koçan üzerindeki yapraklar güneşden en fazla yarar sağlayabilmektedir. (İdikut ve ark., 2020). Koçan altındaki veya koçan üstündeki yaprakların uzaklaştırılmaları arasında verim yönünden önemli farklılıklar olduğu kaydedilmiştir. Yaprakların erken dönemde uzaklaştırılması koçan sıra sayısını, koçan sırasında tane sayısını, tek koçan ağırlığını, tane verimini azaldığı, yaprak uzaklaştırma zamanı geciktikçe tane verimi önemli derecede arttığı, yeşil ve kuru yaprak verimleri, uzaklaştırma şekli ve zamanından etkilendiği kaydedilmiştir (Akıl ve Bengisu, 2020). Metre karede 10 bitkinin yoğunluğundaki mısır bitkisinin yaprak alan indekslerinin (LAI) yaprak uzaklaştırmayla LAI 8.2'den 5.5'e düşürüldüğünde, önemli ölçüde tane verim artışı gözlenmiştir (Liu ve ark, 2009). Koçan püskülü çıkışında, aşırı yaprak uzaklaştırma işlemlerinde, önemli ölçüde besin maddesinin azalmasına ve kuru madde birikiminin azaldığı, fakat tohuma besin taşınması sırasında iki yaprağın uzaklaştırılması önemli ölçüde tohum ağırlığını (% 5.7) ve tohum sayısını (% 6.4) kontrole göre artırdığı rapor edilmiştir (Raza ve ark., 2020). Yüksek bitki yoğunluğunda en üstteki

ve sonraki yaprakları kesilmesi gölgelik fotosentezini ve kuru madde birikimini teşvik ederek, yaprak yaşlanmasının gecikmesine ve daha yüksek besin taşınmasına yol açarak tane veriminin artışını sağlamıştır. Mısır bitkisinin 4 veya 6 yaprağın alınmasıyla, tohum sayısı ve tane ağırlığı önemli düşüş görülmüştür (Liu ve ark, 2015). Mısır bitkisi üzerinde benzer çalışmaların yapılması, yetiştiricilere daha küçük tepe yapraklı mısır çeşitleri geliştirmeleri için yeni bir bakış açısı sağlayacaktır. Ayrıca çiftçilerin verimlerini ve gelirlerini artırmak için mahsul kanopilerini manipüle edecek, bu yeni tarımsal uygulamayı benimsemeleri geliştirilmelidir (Raza ve ark, 2019). Bu çalışmada, mısır bitkisinin yaprakları hayvanlar tarafından sevilerek yemesi, üst yaprakların uzaklaştırılmasından dolayı hasadı öne çekmesi göz önünde bulundurularak, farklı mısır çeşitlerinde tozlanmadan bir hafta sonra koçan üzerindeki farklı bölgelerdeki yapraklar bitkiden uzaklaştırılmasının verim ve verim öğelerine etkisi ve aralarındaki ilişkinin araştırılması amaçlanmıştır.

Materyal ve Metod

Araştırma Akdeniz sahillinde yer alan Adana ili Kozan ilçesi Bucak köyünde yürütülmüştür. Çalışmada dört (D. 6761, P. 1921, P. 2105, Kalumet) mısır çeşidi kullanılarak, tesadüf bloklarında bölünmüş parsel deneme deseninde üç tekerrürlü olarak, 70 cm sıra arası mesafesinde 15 cm sıra üzeri mesafesinde 5 m uzunluğunda ve dört sıra sırta ekim şekilde ekimi gerçekleştirilmiştir. Bitkinin gelişme sürecindeki sulama gübreleme, yabancı ot gibi bakım işleri fizeksel olarak gözlenerek, gerek duyulan işlemler yapılmıştır. Bitkinin azot ve fosfor gereksinimi taban ve üst gübreme olarak dekara net 10 kg fosfor ve 35 azot uygulanmıştır. Yaprak alma işlemleri tozlanma gerçekleştikten bir hafta sonra yapılmıştır. Farklı mısır çeşitlerinde yaprak alma her çeşit için ayrı ayrı yapılmıştır. Yaprak alma 1.Tepe püskülü çıkışından bir hafta sonra koçan yukarısındaki 3 yaprak koparılmış, II. Tepe püskülü çıkışından bir hafta sonra tepe püskülün altındaki 3 yaprak koparılmış, III. Tepe püskülü çıkışından bir hafta sonra koçan yukarısındaki tüm yaprak koparılmıştır. IV. Bu üç uygulama için kontrollerde yaprak alma olmamıştır.
Deneme alanının toprak yapısı çok fazla kireçli, hafif alkalin ph' ya sahip, killi-tın bünyeli, tuzsuz, organik maddesi az, potasyum (K) yüksek, fosfor (P) çok az, çinko (Zn) düşük, demir (Fe) içeriği çok yüksek seviyededir. Akdeniz bölgesinde Haziran-Ağustos aylarında yağışın yok denecek kadar az olması nedeniyle, mısır bitkisinin gelişimini sürdürdüğü dönemde suyu aktif olarak kullandığı için beş kez salma sulama sistemi ile bitkiler sulanmıştır. Bitkiler fizyolojik olgunluğu tamamladıktan sonra, danenin sömeğe bağlandığı yerdeki siyah nokta dikkate alınarak elle hasat edilmiştir. Mısır çeşitlerininin tozlanmadan yedi gün sonra yaprak alma uygulanmıştır. Alınan yaprakların koparıldığı yerden ucuna kadar boyu ve ortasından eni ölçülerek 0.75 katsayı ile çarpılarak ortalama yaprak alanı hesaplanmıştır (Maddoni, and Otegui, 1996). Hasat edilen koçanların üzerinde mısır sıraları sayılarak koçan sıra sayısı, koçanın üzerinde boyuna taneler sayılarak sırada tane sayısı belirlenmiştir. Koçanın üzerindeki taneler elle harmanlanan taneler tartılarak, koçan tane ağırlığı olarak kaydedilmiştir. Taneleri çıkartılmış sömeğin çapı kumpasla ölçülerek belirlenmiştir.
Araştırma sonunda incelenecek özelliklerin istatiksel analizinde JMP 13 paket programı ve ortalamaların kaşılaştırılmasında Duncan çoklu karşılama uygulanmıştır (JMP, 2013).

Bulgular ve Tartışma

Farklı mısır çeşitlerine tozlanmadan 7 gün sonra koçanın yukarısındaki farklı yapraklar uzaklaştırılarak yapılan çalışmada incelenen özelliklerin uygulanan faktörlere ve çeşitlere göre önemli farklılık oluşturduğu Çizelge 1'de görülmektedir.
Mısır çeşitlerinin yaprak alanları, tozlanmadan bir hafta sonra tepe püskülünün altındaki üç yaprağın alanı, koçanın yukarısındaki üç yaprağın alanı, koçan yukarısındaki tüm yaprak ve kontrolün yaprak alanları arasında istatistik önemli farklılığın olduğu ve mısır çeşitlerine göre de önemli farklılık oluştuğu kaydedilmiştir. Tüm çeşitlerde tepe püskülünün altındaki üç yaprağın alanı, diğer uygulamalara göre en düşük yaprak alanına sahip olmuştur. Onu ikinci sırada koçanın yukarısında çıkarılan üç yaprak alanı, üçüncü sırada koçan yukarısı tüm yaprak alanı izlemiştir. En fazla yaprak alanı ise kontrol uygulamasında elde edilmiştir. Genel olarak tepe püskülü altındaki üç yaprak alanı, koçanın altındaki yaprak alanından düşük olduğu görülmüştür. Kontrol ile koçanın yukarısında uzaklaştırılan yaprak alanı arasında ise istatistiki farklılığın olmadığı kaydedilmiştir. Burada kontrol koçanın yukarısındaki tüm yaprakların bitki üzerinde kalması, diğerinde ise koçanın yukarısındaki tüm yaprakların koparılmasıdır. Bu nedenle yaprak alanı yönünden farklılığın olması doğal beklenen bir sonuçtur (Çizelge 1)..
D 6761, P 2105 ve Klument çeşitlerinin koçanın yukarısında farklı bölgelerden yaprak alınanlar ile hiç yaprak alınmayanların sömek çapı arasında istatiksel önemli farklılıklar elde edilmiştir. P 1921 çeşidinin kontrol ile tepe püskülünün altındaki üç yaprağın uzaklaştırılmasıyla uygulaması arasında sömek çapı yönünden istatistiki farklılık oluşturmaz iken, diğer iki uygula arasında önemli farklılık oluşturmuştur. Tüm çeşitlerde koçanın yukarısındaki farklı bölgelerden yaprak uzaklaştırmalardaki sömek çapı kontrol uygulamalarından daha düşük olmuştur. Yürütülen araştırma sonuçlarından sömek çapı üzerinde yaprak alanını olumlu önemli etkisinin olduğu anlaşılmaktadır. Diğer ifadeyle tepe püskülü çıkışından sonra koçanın yukarısındaki yaprakların uzaklaştırması koçan çapının azalacağını ifade etmektedir.

Çizelge 1.Yaprak uzaklaştırılması yapılan mısır çeşitlerinin yaprak alanı, somak çapı, koçan tane ağırlığı, koçan sıra sayısı, sırada tane sayısı özelliklerine ait ortalamalar ve gruplar

	Yaprak alanı (cm^2) **	Somak çapı (cm) **	Koçan tane ağırlığı (g) **	Koçan sıra sayısı (adet) **	Sırada tane sayısı (adet) **
D 6761xTPAÜY	1294.060 ıj	2.63 fg	179.00 fg	20.66 ab	35.00 f
D 6761 KPYÜY	1328.375 ı	2.30 h	172.33 gh	21.00 a	34.33 f
D 6761xKYTY	2937. 037 e	2.13 ı	141.66 k	20.66 ab	35.00 f
D 6761 kontrol	3001.95 e	2.86 bc	262.33 d	21.00 a	35.33 f
P 1921xTPAÜY	1370.587 ı	2.70 ef	185.00 f	17.66 de	45.66 bc
P 1921 KPYÜY	1569.382 h	2.63 fg	170.66 h	16.66 f	47.00 b
P 1921xKYTY	3075.724 d	2.60 g	146.33 jk	16.66 f	46.66 bc
P 1921 Konrol	3086.518 d	2.76 de	292.66 b	17.00 ef	49.00 a
P 2105xTPAÜY	1156.387 k	2.86 bc	192.66 e	17.66 de	46.33 bc
P 2105 KPYÜY	1230. 475 jk	2.90 b	182.66 f	17.66 de	45.33 c
P 2105xKYTY	2638. 573 f	2.83 bcd	154.66 ı	18.00 d	45.00 bc
P 2105 Konrol	2643.28 f	3.06 a	334.44 a	18.00d	46.66 bc
Klumet.xTPAÜY	1100.285 l	2.70 ef	184.00 f	20.00 bc	42.00 de
Klument.x KPYÜY	1205.265 jk	2.70 ef	174.66 gh	19.33 c	41.33 e
Klument xKYTY	2343.436 g	2.60 g	149.66 ıj	20.00 bc	41.00 e
Klımet Konrol	2419.611 g	2.86 bc	280.33 c	21.91 a	43.33 d
Stant sapma	800.047	0.228	58.547	1.759	4.974

*:p<0.05 **: p< 0.01, tepe püskülü altındaki üç yaprak (TPAÜY), koçan püskülünün yukarısındaki üç yaprak (KPYÜY), koçanın yukarısındaki tüm yapraklar (KYTY).

Koçan tane ağırlığı çeşitlere ve koçanın yukarısındaki farklı bölgelerdeki yaprak uzaklaştırılmasına göre istatiksel önemli farklılıklar oluşturmuştur. Tüm çeşitlerde koçan tane ağırlığı, koçanın yukarısındaki farklı bölgelerde yaprak uzaklaştırılması yapılan uygulamalarla, hiç yaprak uygulaması yapılmayan kontrollerle karşılaştırıldığında en yüksek değerlerin kontrol uygulamalarından elde edildiği kaydedilmiştir. Kaçanın farklı bölgelerinde yaprak uzaklaştırma uygulamaları kıyasladığında, koçan tane ağırlığı tepe püskülünün altındaki üç yaprağın alınması, koçanın yukarısındaki üç yaprağın uzaklaştırılmasına göre verim düşüşünün daha az olduğu gözlenmiştir. Diğer bir ifadeyle tepe püskülünün altındaki üç yaprağın, koçanın yukarısındaki üç yapraktan daha fazla tane verimine katkı sağladığı anlaşılmaktadır. Koçanın yukarısındaki tüm yapraklar alındığında ise tepe püskülünün altındaki üç yaprağın, koçanın yukarısındaki üç yapraktan daha fazla verim düşüşüne neden olduğu kaydedilmiştir. Bu sonuç mısır bitkisinin tozlanmasından 7 gün sonra olmasına rağmen koçanın yukarısındaki yaprakların verime katkısının farklı olduğu ve tepe püskülüne yakın olan üst yapraklarım verime etkisinin daha yüksek olduğu anlaşılmaktadır. Kontrol uygulamasındaki tane verimi irdelendiğin, tepe püskülü çıkışından bir hafta sonra koçanın yukarısındaki tüm yaprakların uzaklaştırılması yaklaşık % 50 verim düşüşüne neden olacağı, mısırda döllenmeden sonraki dönemle yaklaşık % 50 besin birikimin devam edeceğini göstermektedir. Bu nedenle mısır bitkisinde dönemeden sonrada bitki gereksinimi dikkatlice takip edilerek, yüksek verim için gerekli çevre koşullarının sağlanması gerekmektedir

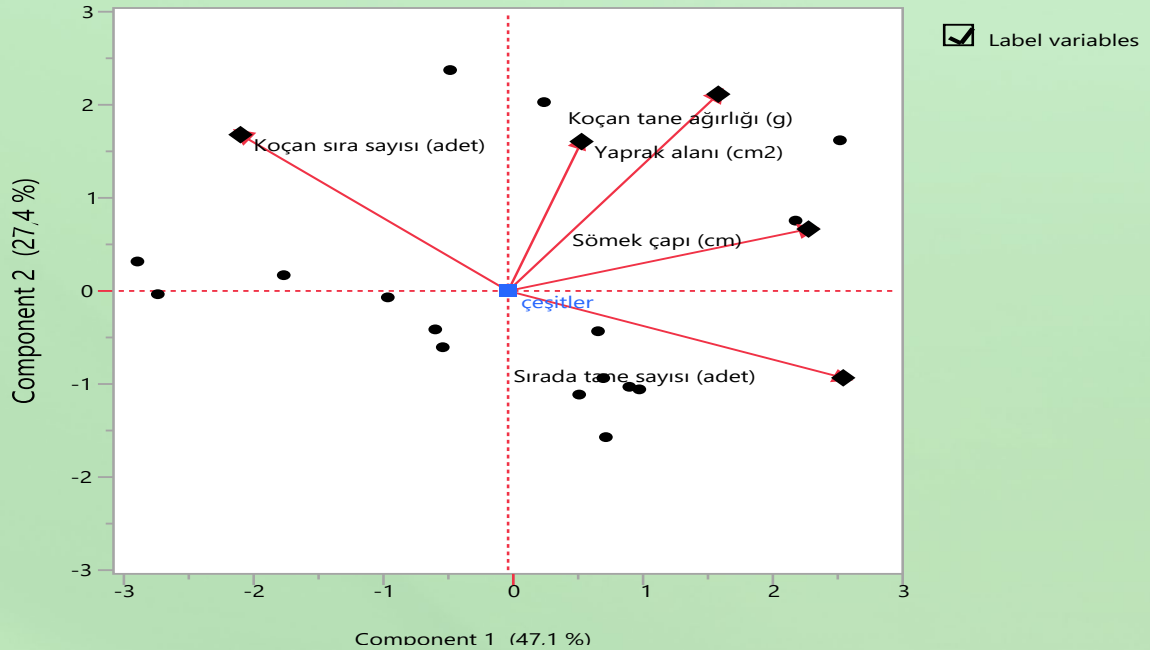
Mısır çeşitlerinde tozlanmadan 7 gün sonrasında, tepe püskülü altında, kaçan püskülü yukarısındaki üç yaprağın, tüm yaprakların uzaklaştırılması ve kontrollerin koçanda sıra sayısı çeşitlere göre farklılık göstermiştir. Kaçanın yukarısındaki farklı bölgelerden yaprak uzaklaştırmanın D 6761 ve P 2105 çeşitlerinin kaçanda sıra sayısı üzerine önemli etkisi olmamıştır. P. 1921 çeşidi koçanı yukarısındaki üç yaprağın ve kaçanın yukarısındaki tüm yaprakların uzaklaştırılması ile kontrolle arasında farklılık oluşturmadığı kaydedilmiştir. Tepe püskülü aşağısındaki üç yaprağın uzaklaştırılması ile koçanın yukarısındaki üç ve tüm yaprakların uzaklaştırılmasında oluşan koçanda sıra sayısı arasında istatistiki farklılık oluşmuştur. Klumet çeşidinin koçanda sıra sayısı kontrole ile farklı bölgelerden yaprak uzaklaştırma arasında önemli farklılık kaydedilmiştir. Kaçan sıra sayısı verim unsurlarından biri olmakla birlikte çeşit özelliği çevresel faktörlerden daha baskındır, bu nedenle farklı yaprak uzaklaştırmanın etkisi çok net görülememiştir (Svecnjak ve ark. 2006; Abendroth ve ark. 2011)

Koçan sırasında tane sayısı koçanın yukarısında farklı bölgelerden yaprak uzaklaştırma ve çeşitlere göre istatiksel farklılık göstermiştir. En yüksek koçan sırasında tane sayısı P 1921 çeşidinde kaydedilmiştir. P. 1921 çeşidinin koçanın yukarısında farklı bölgelerden yaprak alınanlar ile hiç yaprak alınmayanların koçan sırasında tane sayısı arasında istatiksel önemli farklılıklar elde edilmiştir. En yüksek sırada tane sayısı hiç yaprak alınmayan kontrol uygulamasından elde edilmiştir. D 6761 ve P 2105 çeşitlerinin kaçanın yukarısındaki farklı bölgelerden yaprak uzaklaştırmanın kaçan sırasında tane sayısına istatistikse etkide bulunmamıştır. Klumet çeşidi koçanı yukarısındaki üç yaprağın ve kaçanın yukarısındaki tüm yaprakların uzaklaştırılması ile tepe püskülü aşağısındaki üç yaprağın uzaklaştırılması koçan sırasında tane sayısı yönünden istatistiki önemli farklılık görülmemiştir. Fakat

kontrol ile koçanın yukarısında tüm yaparak ve üç yaprağın uzaklaştırılması koçan sırasındaki tane sayısında istatistiksel önemli farklılık kaydedilmiştir. Tüm çeşitlerde koçanın yukarısındaki farklı bölgelerden yaprak uzaklaştırmalarda koçan sırasında tane sayısı kontrollerden daha düşük olarak gerçekleşmesi, koçan sırasında tane sayısının çevresel faktörlerden ekileneceğini ifade etmaktedir (Çizelge 1).
Mısır çeşitlerinin yaprak alanı, somak çapı, koçan tane ağırlığı, koçan sıra sayısı, sırada tane sayısı ait correlations Çizelge 2. verilmiştir. Araştırmada kullanılan çeşitlerin incelenen özelliklerine ait temel bileşenler analizi Şekil 1'de verilmiştir .

Çizelge 2. Mısır çeşitlerinin yaprak alanı, somak çapı, koçan tane ağırlığı, koçan sıra sayısı, sırada tane sayısı ait correlations.

	Yaprak alanı (cm2)	Sömek Çapı (cm)	Koçan tane ağırlığı (g)	Koçan sıra sayısı (adet)	Sırada tane sayısı (adet)
Yaprak alanı (cm2)	1,0000	-0,0027	0,3333	-0,0241	0,0717
Sömek çapı (cm)	-0,0027	1,0000	0,6213	-0,3109	0,5790
Koçan tane ağırlığı (g)	0,3333	0,6213	1,0000	0,0451	0,2570
Koçan sıra sayısı (adet)	-0,0241	-0,3109	0,0451	1,0000	-0,8276
Sırada tane sayısı (adet)	0,0717	0,5790	0,2570	-0,8276	1,0000



Şekil 1. Mısır koçan yukarısında yaprak uzaklaştırma işlemi yapılan D. 6761, P. 1921, P. 2105 ve KWS Klument çeşitlerinin yaprak alanı, sömek çapı, koçan tane ağırlığı, koçan sıra sayısı, koçan sırasında tane sayısı özelliklerine ilişkin biplot grafiği.

D. 6761, P. 1921, P. 2105 ve Klumet mısır çeşitlerine farklı yaprak alma uygulaması sonucunda yaprak alanı ile koçan tane ağırlığı, sömek çapı ve sırada tane sayısı arasında olumlu ve önemli ilişkinin olduğu görülmektedir (Çizelge 2). Yaprak alanı ile koçan sıra sayısı arasında ise yaklaşık 90 derececelik bir açının olduğu ve nört bir ilişkinin olduğu anlaşılmaktadır. Sırada tane sayısı ile koçan sıra sayısı arasında ise negatif bir ilişki gözlenmiştir. Temel Bileşen 1 (47.1%) ve 2 (27.4%) varyasyonun % 74.5'ini açıklamıştır (Şekil 1). Bu durum yürütülen araştırmanın önemini vurgulamakla birlikte, mısır bitkisinin koçan yukarısındaki yaprakların verime katkısının önemini açıklamaktadır.

Tartışma

Dört hibrid mısır çeşitleri Nisan-Eylül ayları arasında Adana-Kozan ilçesi Bucak köyünde civarında yetiştiriciliği yapılmıştır. Hibrid mısır çeşitlerinin tepe püskülü çıkışından yedi gün sonra; a) koçanın tepe püskülü altındaki üç yaprak, b) koçan yukarısındaki üç yaprak, c) koçanın yukarısındaki tüm yapraklar, d) kontrol olmak üzere dört farklı yaprak alma işlemi uygulanmıştır. Yaprak alma uygulamalarında alınan yaprakların alanları hesaplanmıştır. Söz konusu uygulamalar eşliğinde tane nemi % 14-15 düştüğünde, ürün hasadı yapılarak, koçan somek çapı, tane

ağırlığı, koçan sıra sayısı, koçan sırasındaki tane sayıları incelenmiş ve Principal Components analiz kullanılarak aralarındaki ilişki tespit edilmiştir. Araştırmada kullanılan D. 6761, P. 1921, P. 2105 ve KWS Klumet mısır çeşitlerinin hepsinde en yüksek yaprak alanının kontrol uygulamasında olduğu, onu ikinci sırada koçan yukarısındaki tüm yaprakların alınması, üçüncü sırada ise koçanın yukarısındaki üç yaprak alma uygulasının izlediği görülmüştür. En az yaprak alanının ise tüm çeşitlerde tepe püskülü altındaki alınan üç yaprak alanında kaydedilmiş. Hibrid mısır çeşitlerinde en az somak çapı kaçan yukarısındaki tüm yaprakların uzaklaştırılmasında, en yüksek ise kontrol uygulamasından elde edilmiştir. Somak çapının yaprak alanının uzaklaştırılasıya azalması fotosentez yapacak verim bileşenin azalmasından kaynaklanmıştır. Adhikari et al. (2021) ifade ettiği gibi mısır bitkisine uygulanan gübre dozunun artmasıyla somak çapının artması çevresel faktörlerin etkisini açıklamaktadır. Koçan tane ağırlığındada en yüksek değer hiç yarak kaparılmayan konrol uygulamadan, en az koçan tane ağırlığı koçan yukarısındaki tüm yaprak almada kaydedilmiştir. Denenen mısır çeşitlerinde koçanın yukarısındaki üç yaprağın uzaklaştırılması uygulamasında koçan tane ağırlığının tepe püskülü altındaki üç yaprağın uzaklaştırılmasından daha düşük olduğu belirlenmiştir. Cokkızgın ve ark. (2022) uygulanan gübre dozlarına ve yıllara göre koçan tane ağırlığının değiştiğini ve çevresel faktörlerden etkilendiğini kaydetmişlerdir. Koçan püskülü çıkışında, aşırı yaprak uzaklaştırma işlemlerinde, önemli ölçüde besin maddesinin azalmasına rapor edilmiştir (Raza ve ark., 2020). Yaprak alanı, yaprağın morfolojik özellikleri, çevre faktörleri verime etki eden faktörler olduğu bilinmektedir (Li et al., 2021; Reddy et all., 2010). Diğer ifadeyle tepe püskülü aşağısındaki yaprakların, koçanın yukarısındaki yapraklardan daha fazla tane verimine katkısının olduğu tespit edilmiştir. Mısır bitkisinde yaprak alanları tepe püskülüne doğru azaldığı, fakat tane verimine katkısının daha fazla olduğu vurgulanmıştır (Yetişti ve Soylu, 2020). Mısır çeşitlerinin koçan sıra sayısı ve sırada tane sayıları kontrol uygulamalarında daha yüksek bulunmuştur. Koçanın yukarısındaki tüm yaprakların, koçanın üstündeki üç yaprağın ve tepe püskülü altındaki üç yaprağın uzaklaştırılmasında, koçan sıra sayısı ve sırada tane sayısı farklılık gösterdiği, söz konusu farklılığın yaprak uzaklaştırma uygulamalarından bağımsız farklılığın olduğu anlaşılmaktadır. Bu durum koçanda sıra sayısı ve sırada tane sayısının koçan ve tepe püskülü çıkışından önce büyüme konisindeki oluşumla ilgili olduğu düşünülmüştür (Rai et al., 2021). Araştırmada incelenen özelliklerden yaprak alanı ile somak çapı ve koçan dane ağırlığı arasında önemli ilişkinin olduğu kaydedilmiştir (Liu ve ark., 2015). Yaprağın verim bileşenlerden ilk sırada yer aldığı kabuledilmektedir (Pereira ve ark. (2012).

Sonuç

Araştırmada D. 6761, P. 1921, P. 2105 ve KWS Klumet hibrid mısır çeşitlerinin döllenme oluştuktan yedi gün sonra koçanın tepe püskülü altındaki üç yaprak, koçan yukarısındaki üç yaprak, koçanın yukarısındaki tüm yapraklar ve kontrol olmak üzere dört farklı yaprak alma işlemi uygulanmıştır. Çeşitlerin yaprak alma uygulamalarındaki yaprak alanları, hasat olgunluğun elde edilen koçanların tane ağırlıkları, sömek ağırlıkları, koçan sıra sayıları ve sırada tane sayıları özellikleri incelenerek aralarındaki ilişki belirlenmeye çalışılmıştır. Sonuç olarak koçanın yukarındaki yaprakların alanlarının tepe püskülüne doğru azaldığı, tepe püskülünün altındaki yaprakların koçanın üstündeki yapraklardan daha fazla verime etkisinin olduğu, yaprak alanı ile koçan tane verimi arasında yakın ilişkinin olduğu, yaprak uzaklaştırma uygulamaları ile koçanda sıra sayısı ve sırada tane sayısı arasında istatistiksel farklılık olmakla birlikte aralarındaki ilişkinin bağımsız olduğu belirlenmiştir.

Araştırmacıların Katkı Oranı Beyan
Makalede yazarlar eşit katkı oranları sahiptir.

Çıkar Çatışması Beyanı
Makale yazarları aralarında çıkar çatışması bulunmamaktadır.

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The Importance of Eco-Friendly Materials in the Food Industry

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Abstract

This review article explores the importance of eco-friendly materials in the food industry. Eco-friendly materials, often called green or environmentally friendly materials, are becoming increasingly popular in various sectors that aim to benefit the environment. One of the key advantages of using these materials is that they are often made from recycled or renewable resources. This approach helps to reduce waste, lower greenhouse gas emissions, and minimize carbon footprints. This is especially important in the food sector, like biofilm food packaging, beeswax food wraps, and waste food to ethanol. In addition, targets food protection and reduces environmental pollution.

Keywords: *eco-friendly, food industry, organic waste.*

Introduction

In the modern world, industries have developed a direction for eco-friendly materials, also known as environmentally friendly or green materials, which aim to utilize natural substances to benefit our environment (Abdur Rahman et al., 2023; Nowotna et al., 2019). One of the significant benefits of using eco-friendly materials is that they are often sourced from renewable or recycled resources, which helps reduce carbon footprints, greenhouse gas emissions, and waste (Abera, 2024). These materials can come from various sources, including plants such as bamboo, cork, and hempcrete (Orhon & Altin, 2020); agricultural waste such as fruits, vegetables, and grains (Kılınç & Korkmaz, 2024; Xie, Y. 2020; Kocabaş et al., 2021); as well as animal sources like crab, lobster, shrimp (Bakshi et al., 2000), and cow (Nowotna et al., 2019). Industries can greatly reduce their environmental impact by choosing materials that require less energy to produce and are either biodegradable or recyclable. This is especially important in the food industry and other sectors. It is essential to note that while all biodegradable products can be viewed as eco-friendly regarding waste decomposition, not all eco-friendly products are biodegradable. Some may be recyclable, reusable, or mitigate environmental impact differently.

Many sectors of the food industry are concerned about grocery spoilage and contamination due to microbes and lipid oxidation (Pinto et al., 2017). These issues render food products unsafe for consumption and can result in substantial financial losses. Effective food packaging can help reduce microbial spoilage, minimized lipid oxidation, extend shelf life, and enhance the visual appeal of food products.

The importance of eco-friendly materials in the food industry was studied under the titles a: biodegradable material used as biofilm or bio-plastic (starch, gelatin, and chitosan package), beeswax food wrap, and b: food and agriculture waste can produce biofuels such as bioethanol.

Biodegradable material used as biofilm or bioplastic

Plastic and food waste contribute significantly to environmental pollution and health issues (Ramadhan, 2020; Verma et al., 2016; Jambeck et al., 2015). As consumers become more aware of health and well-being, the transfer of substances from food packaging materials to the food itself has sparked debate among legal experts and researchers. Researchers are also working to reduce plastic waste by converting food waste into biodegradable packaging. These materials (biopolymers) can break down and return to natural elements within a short time in the environment, helping to protect our surroundings (Song et al., 2009; Mohammadalinejhad et al., 2020). Figures 1 and 2 several biodegradable materials are found in our environment, including polysaccharides, proteins, and lipids (Cazon et al., 2017; Nasrollahzadeh et al., 2020; Wu et al., 2017).

Polysaccharides and proteins are biopolymers derived from organic waste, bamboo plants, cork, and hempcrete. Although they currently hold little economic value, they offer a cost-effective option for use as biodegradable films, additives, or preservatives (Samrot et al., 2020). Recent research has explored the use of bioactive polyphenolic pigments extracted from food waste to create biodegradable films (Bhargava et al., 2020). These films can serve as eco-friendly and sustainable packaging materials.

A large number of studies have been conducted on biofilm packaging materials, such as polysaccharide films (including chitosan, starch, cellulose, and pectin), as highlighted by Cazon et al. in 2017; protein films (such as casein, whey, and gelatin) referenced by Chen et al. in 2019; and lipid films (like waxes) discussed by Callegarin et al., in 1997. These packaging materials demonstrate excellent oxygen barriers, adequate protection against oil and gas, antimicrobial properties, antioxidant strength, and flexibility (Moeini et al., 2022; Trinh et al., 2023).

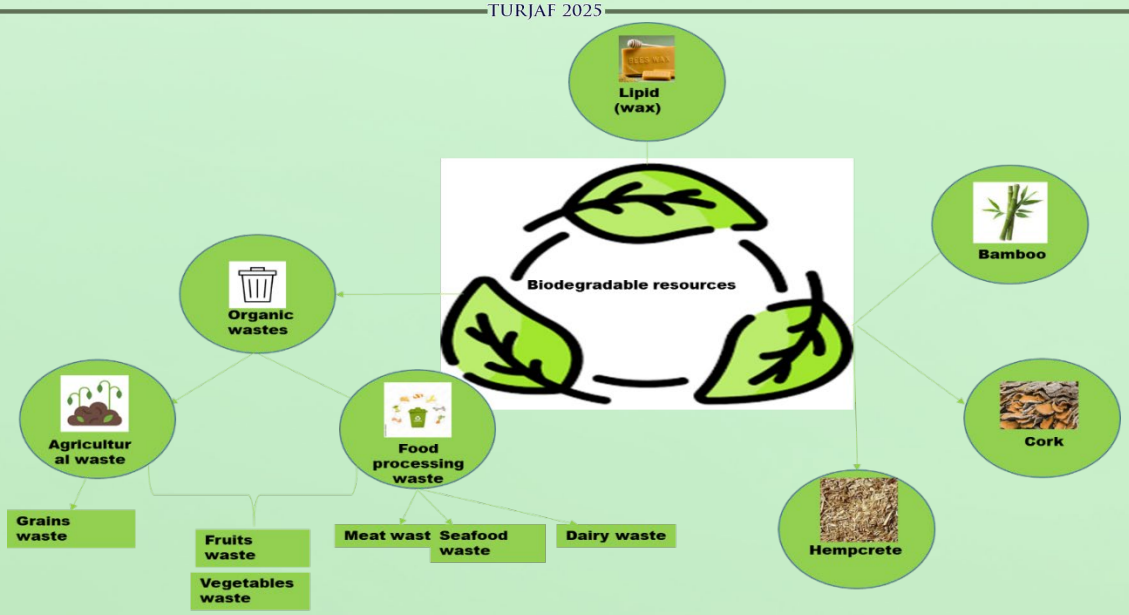


Figure 1. A brief overview of the classification of biopolymers by modified Popoola and Bukola (2022).

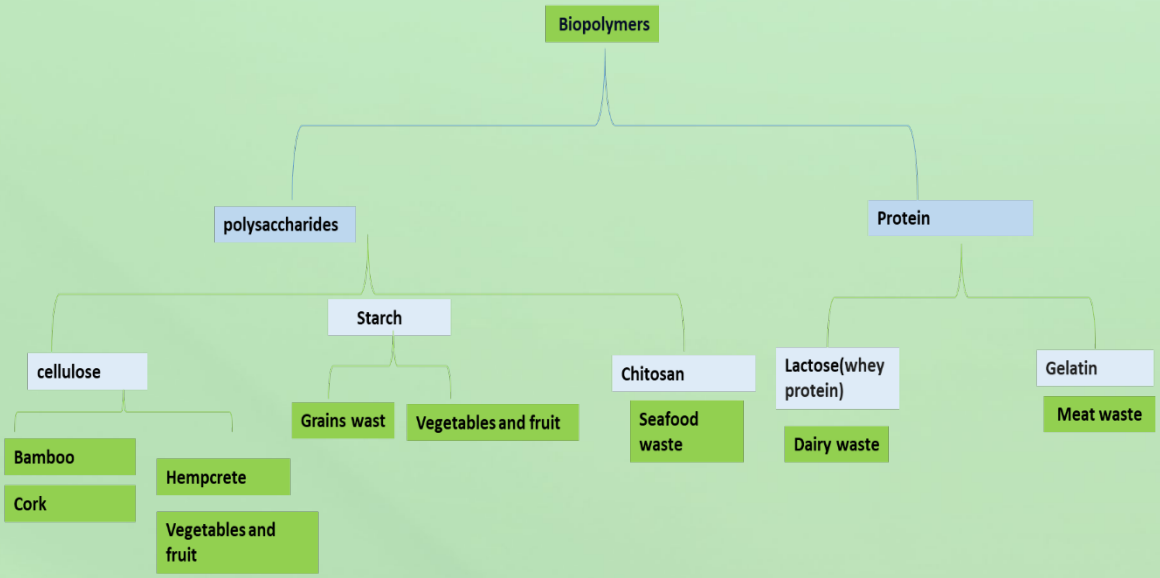


Figure 2. A brief overview of the classification of biopolymers. Inspired from Rhim et al. 2013 and Samrot et al. 2020.

Beeswax food wrap

Beeswax is a naturally antibacterial substance commonly used to create food wraps. It is biodegradable, sustainable, compostable, and environmentally friendly (Gupta et al., 2023).

Beeswax wraps are made from organic cotton, beeswax, plant oils, and tree resin, and they are promoted as a durable and flexible alternative to plastic wrap (Skiver, 2023). Some studies indicate that beeswax can positively affect the shelf life of food. Research from Fratini et al. (2016), Ghanem Nevine (2011), and Kacániová (2012) has reported that beeswax possesses antimicrobial properties, which may inhibit the growth of bacteria and fungi. Additionally, Pinto et al. (2017) found that Abeego wraps could inhibit food-borne bacterial pathogens and help prevent food spoilage.

Waste Food to Ethanol

Bioethanol has been utilized in the transportation and energy sectors for decades (Akin et al., 2021). It is produced from various sources, including sugarcane waste, food waste, biomass feedstocks, and crops such as corn and wheat (Byadgi & Kalburgi, 2016; Braide et al., 2016). This production can occur without negatively impacting the food supply or land use. Biomass energy is becoming increasingly popular as a clean and sustainable energy source (Bhatia et al., 2023).

One significant advantage of diverting food waste from landfills is reducing greenhouse gas emissions. When food waste decomposes in landfills, it generates methane, a potent greenhouse gas that contributes to climate change. By converting food waste into biofuel instead of allowing it to decompose in landfills, we can prevent methane release and significantly reduce our carbon footprint (Bhatia et al., 2032).
Additionally, a study by Gauder et al. (2011) showed that Brazilian food production increased fivefold from 1961 to 2008, with sugarcane crops representing 3% of agricultural production. This research analyzed the competition between bioethanol production and food production, revealing that over 20 million hectares of land will be available for agricultural production in the future. Three scenarios were explored, indicating that primary food production could increase 1.5 times and bioethanol production 1.8 times between 2007/2008 and 2020. This growth could meet 38% of the total energy demand in the Brazilian transport sector.

Conclusions

Biodegradable materials have become essential in our lives due to their significant impact on our environment and health. These materials are derived from natural sources, such as organic waste from food and agriculture, which are both abundant and cost-effective. Additionally, they offer antimicrobial and antioxidant properties, enhancing the performance of packaging systems. Moreover, biodegradable materials can be utilized as biofuels, such as bioethanol, in the food, transportation and energy sectors beyond. Developing biodegradable materials from food and agricultural waste offers several benefits, as it reduces the reliance on plastics, decreases plastic waste, and minimizes food waste simultaneously. This approach promotes overall environmental sustainability.

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Garlic and Ginger Pastes as natural Antioxidant in Spent Hen Meat Nugget

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Abstract

Economic value of spent hen can be improved through value addition. However, spent hen contain high fat and coupled with the fact that processed chicken meat is more susceptible to oxidative deterioration make spent hen meat products prone to oxidative degradation. Therefore, the need for antioxidant inclusion during spent hen meat product formulation. Five spent hen chicken nugget emulsions were formulated (T1 ascorbic); T2 0.5% Garlic, T3 1.0% Ginger, T4 0.5% Ginger, T5 1.0%Ginger. The mixtures from each formulation were filled into boxes (20×10 cm) (approximately 40±1 g each), deep fried in Grand Soya oil® for 10 minutes at 190±2ºC (frying temperature). The fried nuggets were allowed to cooled down to room temperature and a portion from each nugget was packaged in air tight zip loc bags and stored in a refrigerator (4ºC). Frying yield (%), phenol content (GAEmg/g, flavonoid (mg QE/g), cholesterol (%) and Thiobarbituric reactive substances (TBARS) mg MDA/kg). (Data generated were analysed using ANOVA@Pα0.05.

Frying yield 92.29 (0.5% ginger) is similar to 88.62 (0.5% garlic) and significantly higher than 82.29 (ascorbic) and 85.72 (1.5% garlic) but significantly lower than 97.87 (1.5% ginger). Nugget with 1.5% ginger had 24.92 phenol content which is significantly lower ($P<0.05$) than 20.47 (0.5% ginger), 18.37 (1.5% garlic), 17.63 (0.5% garlic) and 16.06 (ascorbic). Flavonoid (9.34) and cholesterol (72.82) contained in ascorbic nugget is significantly higher than 8.20; 61.84 (0.5 ginger), 8.69; 57.09 (1.5% ginger), 4.71; 68.49 (0.5% garlic) and 6.32; 59.05 (1.5% garlic) for flavonoid and cholesterol respectively. Irrespective of the storage days, ascorbic nuggets had higher TBARS levels than nuggets with ginger and garlic pastes.

The reduced cholesterol contents and low levels of TBARS in the spent hen chicken nuggets with ginger and garlic pastes elucidated that both spices can be part of spent hen chicken nuggets formulation.

Keywords: *Nuggets, Oxidative deterioration, Spent hen, Value addition, Scavenging radicals*

ID: 409

The direction of broiler farming research in recent decades

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Abstract

To understand the direction of broiler farming research over the past few decades, this study was conducted using Web of Science as a database. A total of 29,193 documents were published on this platform from 2014 to 2024 on various topics related to broilers. 91.86% of the existing documents were published in the form of scientific articles and the most popular categories of publications are none other than "Agriculture Dairy Animal Science" and "Veterinary Sciences**".** In terms of publication reviews, "Poultry Science" and "Animals" have been the most requested for the publication of studies conducted on broilers over the last 10 years. As for the most productive countries in terms of producing scientific documents, China and the United States have largely distinguished themselves from other countries internationally, strengthening their reputation in broiler farming. Given the vastness of the database, a combination of keywords and two filters were used. For the analysis of the data, only the top 50 most referenced and cited studies were considered. The analysis of the documents made it possible to understand that many studies have been carried out on key themes such as genetics, egg incubation, stress on broilers, nutrition, the use of antibiotics, avian diseases and on the behavior of poultry in the rearing environment. However, topics related to sperm quality, climate change, effluent management and greenhouse gas reduction are still underexplored and will certainly be the subject of future research.

Keywords: *Broilers, research, animal welfare, genetics, stress, Web of Science*

Introduction

Scientific research is research conducted with the goal of contributing to science through the systematic collection, interpretation, and evaluation of data in a planned manner (Ozhan Caparlar & Donmez, 2016). It is essential to produce new knowledge to better understand a situation or a phenomenon. It is also an essential pillar for the development of technological and social innovations. For many decades, scientific research has experienced a certain expansion, but in recent years this trend has been more accelerated. In fact, in 2022, more than 5.14 million scientific articles were published worldwide, an increase of 22.78% since 2018 (Benjamin et al., 2023).

Whether in the field of human, animal, technological or other sciences, it should be noted that no sector that wants to evolve can achieve this without the help of scientific research and the livestock sector is no exception. Protein contributes to nearly 40% of total agricultural production in developed countries and 20% in developing countries, and supports the livelihoods of at least 1.3 billion people worldwide (FAO, 2025). Even if the contribution of the livestock sector is not limited to the production of meat, milk and eggs, However, it would be difficult to fully meet the nutrient needs of the population without it. Foods of animal origin make a critical contribution to global nutrition and are an excellent source of macro- and micronutrients (Mottet et al., 2017).

At the same time, livestock products account for 18% of global calories, 34% of global protein consumption and provide essential micronutrients, such as vitamin B12, iron, zinc and calcium that can be locally difficult to obtain in adequate amounts from plant-based foods alone (Murphy & Allen, 2003; Randolph et al., 2007). However, we cannot talk about the livestock sector without talking about broilers. Indeed, broiler farming is by far the largest land-based animal production industry in the world, with around 70 billion broilers slaughtered each year (Butterworth, 2021).

In 1920, for a broiler to reach the weight of 1,500 g, it took 120 days, 44 days in 1980 and only 33 days in 1998 (GAA Albers & Ir. A. Groot, 1998). Since 2005, it is possible for broilers to reach between 1,700 g and 2,200 g of live weight after only 28 days of rearing and to more than 3,500 g in only 56 days of rearing if and only if the appropriate breeding conditions are respected (Zuidhof et al., 2014). In other words, the live weight at 6 weeks of the animals has been multiplied by 3 in 50 years (from 1 to 3 kg) and the net yields by 1.7 in 30 years (Berri & Jehl, 2001).

Over the years, it is therefore obvious that broilers have experienced a huge improvement in their productivity, thanks to the simultaneous progress of genetics, nutrition, breeding methods and veterinary medicine. To put it simply, the productivity of broilers has increased in recent years largely thanks to the various scientific research

carried out in the field. In other words, without advances in scientific research, none of its results would have been possible.

Since each discovery of scientific research is only the continuation of past results and experiments, this study was initiated with the aim of taking stock of the direction of research in broiler farming over the last decade. Understanding the direction of research at the level of broiler farming will allow us to look back on the progress already made, but also to highlight the future challenges for efficient, sustainable and even more environmentally friendly production.

Materials and methods

To carry out this study on the orientation of the Research on broiler farming Over the past ten years, the first step has been the selection of a database. The choice fell on Web of Science (WoS) rather than Scopus, PubMed or other databases because it is not a simple catalogue of academic publications. WoS is a selective, structured and balanced database, with comprehensive citation links and enhanced metadata, that meets a wide range of information purposes (Birkle et al., 2020). It is also a selective index of citations of scientific and academic publications covering journals, proceedings, books and data compilations. (Birkle et al., 2020).

The first data were obtained using the keyword "broilers" and excluding data not belonging to the last decade. In other words, only data from 2014 to 2024 on broilers were considered. As a result, more than 29,000 documents were found. Given the number of documents found, only information concerning the "type of documents published", the "Web of Science categories", the "publication journals" and the "countries" that have published on the subject were considered for the analysis of the data in the first instance.

To reduce the size of the database previously obtained, the key theme of this study was pooled with other keywords such as "genetics", "health and well-being", "antibiotics", "diseases", "behavior" and other keywords using "AND" as a Boolean operator in a second step. For example, the combinations "genetic AND broilers", "antibiotic broilers AND", etc. were used. By combining these different keywords two by two with the main theme, the data could be halved in some cases and more in others. However, to filter the data as much as possible, to obtain precise documents on the different keywords used, two additional filters were used. Indeed, the keywords used should be found in the "Title" as well as in the "Author's keywords".

For the analysis of the data in this specific case, only the top 50 most referenced and cited studies, as well as the countries that have produced the most publications related to the association of the key theme and the different keywords previously mentioned were examined. No special software was used for data analysis, as on the WoS platform there are the "Analyze Results" and "Citation Report" options. These two different options alone have made a great contribution to data analysis, as they promote efficient and timely analysis of trends, areas of research, and citations.

However, it is important to note that the most cited and referenced studies are not always representative in terms of research quality. As a result, many of the research findings may not be considered in this study. At the same time, the study of about fifty studies does not allow for an in-depth study of the available literature, even if many of the studies have been repetitive. In addition, by using the filter, many documents will not be considered, but by adding the presence of the keywords used in the abstracts of the articles, it could further enlarge the literature obtained and at the same time enrich the results obtained in this study. Regarding the third part, a conclusion was drawn for this study.

Data analysis

Status of Broiler Publications from 2014 to 2024

Table 1 shows the 10 different types of documents that exist in terms of the literature available on broilers according to the Web of Science database.

Table 1. Summary of the types of documents existing on the broilers

Document Types	Record Count	% of 29 193
Article	26817	91.861
Review Article	1456	4.987
Proceeding Paper	479	1.641
Meeting Abstract	329	1.127
Book Chapters	194	0.665
Correction	138	0.473
Early Access	125	0.428
Editorial Material	55	0.188
Retracted Publication	26	0.089
Letter	20	0.069

According to Table 1, there are 29,193 documents available on broilers. Of these, 26,775 documents were published in the form of scientific articles, i.e. 91.86% of the existing documents. 1,455 documents were published in the form of review articles, i.e. 4.99% of the existing documents. The remaining documents were published as working papers, summaries of meetings, or in the form of a book and other chapters.

Scientific production by country

Table 2 presents the different countries that are most active in terms of the production of documents on topics related to broilers.

Table 2. Scientific production according to country

Countries/Regions	Record Count	% of 29 193
CHINA	5497	18.830
USA	4823	16.521
BRAZIL	2258	7.735
IRAN	2068	7.084
EGYPT	1556	5.330
PAKISTAN	1147	3.929
INDIA	1066	3.652
POLAND	1006	3.446
CANADA	991	3.395
GERMANY	978	3.350

According to Table 2, China and the United States are the countries that have distinguished themselves the most through their quantitative contribution to research related to broilers. China alone published 5,489 documents, or 18.11% of the available literature on broilers. The USA produced 4810 documents, or 16.5% of the total production. In addition, countries such as Brazil, Iran, Egypt, Pakistan, India and others have also contributed to the production of scientific papers on broilers.

Most Active Web of Science Categories

Table 3 presents the different categories within which scientific publications on broilers have been indexed in the Web of Science database.

Table 3. categories Web of Science

Web of Science Categories	Record Count	% of 29 193
Agriculture Dairy Animal Science	14511	49.707
Veterinary Sciences	7646	26.191
Food Science Technology	1913	6.553
Microbiology	1761	6.032
Zoology	1720	5.892
Agriculture Multidisciplinary	1603	5.491
Multidisciplinary Sciences	986	3.378
Biotechnology Applied Microbiology	977	3.347
Environmental Sciences	948	3.247
Biochemistry Molecular Biology	779	2.668

As regards the categories into which the scientific studies conducted on broilers were divided, it is apparent from Table 3 that almost half of the documents, i.e. 14 511 documents existing in the Web of Science database, were categorised in the section 'Agriculture Dairy Animal Science'. Apart from this category, which stood out significantly, there are also 7,646 documents that were divided into the "Veterinary Sciences" category. Other Web of science categories such as Food Science Technology, Microbiology, Zoology and Agriculture Multidisciplinary also stood out with more than 1500 documents in each of them.

The most active scientific journals

Table 4 shows the scientific journals that have published the most articles on topics related to broiler farming.
According to Table 4, journals such as "Poultry Science" and "Animals" have been the most solicited for the publication of studies conducted on broilers over the last 10 years. Each of them has more than 1,200 articles published on topics related to broilers. Journals such as the Journal of Applied Poultry Research, British Poultry Science, Brazilian Journal of Poultry Science and others individually published an average of more than 340 articles on topics related to broiler farming.

Table 4. The most productive scientific journals

Publication Titles	Record Count	% of 29 193
POULTRY SCIENCE	3927	13.452
ANIMALS	1244	4.261
JOURNAL OF APPLIED POULTRY RESEARCH	658	2.254
BRITISH POULTRY SCIENCE	575	1.970
BRAZILIAN JOURNAL OF POULTRY SCIENCE	559	1.915
FRONTIERS IN VETERINARY SCIENCE	455	1.559
JOURNAL OF ANIMAL SCIENCE	448	1.535
PLOS ONE	424	1.452
JOURNAL OF ANIMAL PHYSIOLOGY AND ANIMAL NUTRITION	396	1.356
ANIMAL FEED SCIENCE AND TECHNOLOGY	377	1.291

The most productive countries in terms of publishing scientific papers in the field of genetics at the broiler level

Figure 1 shows the 10 countries that have published the most literature in the field of genetics for the optimization of broiler farming. According to Figure 1, on genetic issues related to broilers, a total of 2,079 documents are available on the Web of Science database. In addition, the USA with 415 documents and China with 399 documents to their credit are the countries that have published the most articles on this topic over the last decade.

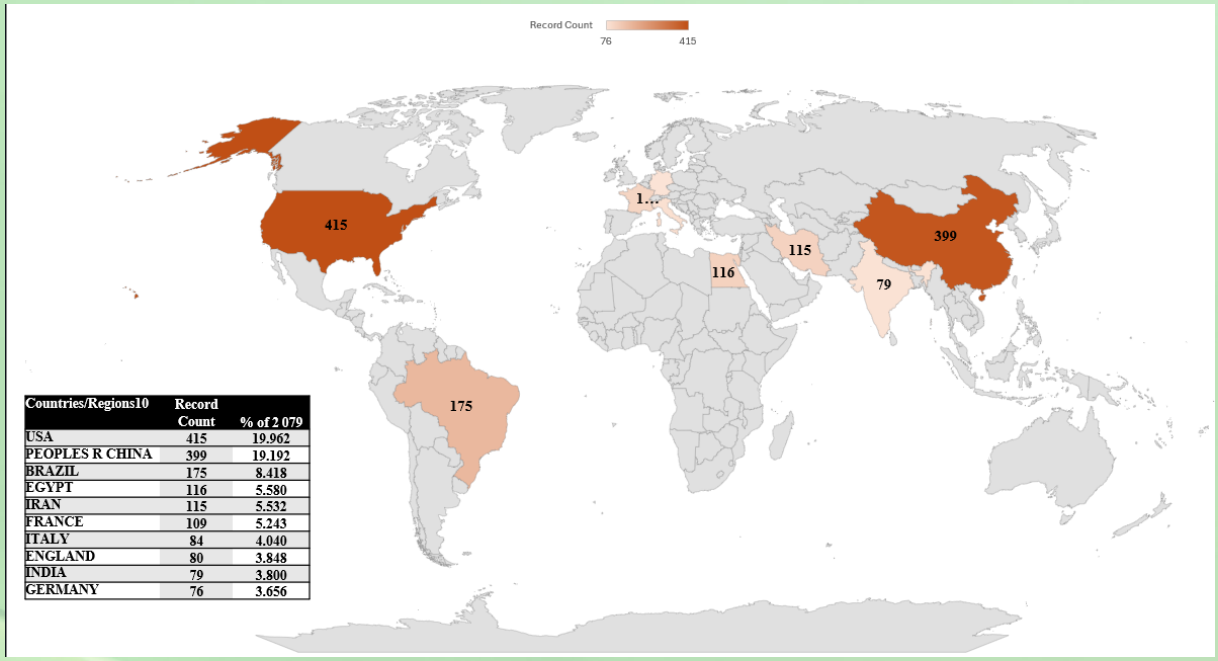


Figure 1. Most productive countries in terms of documents in the genetics sector

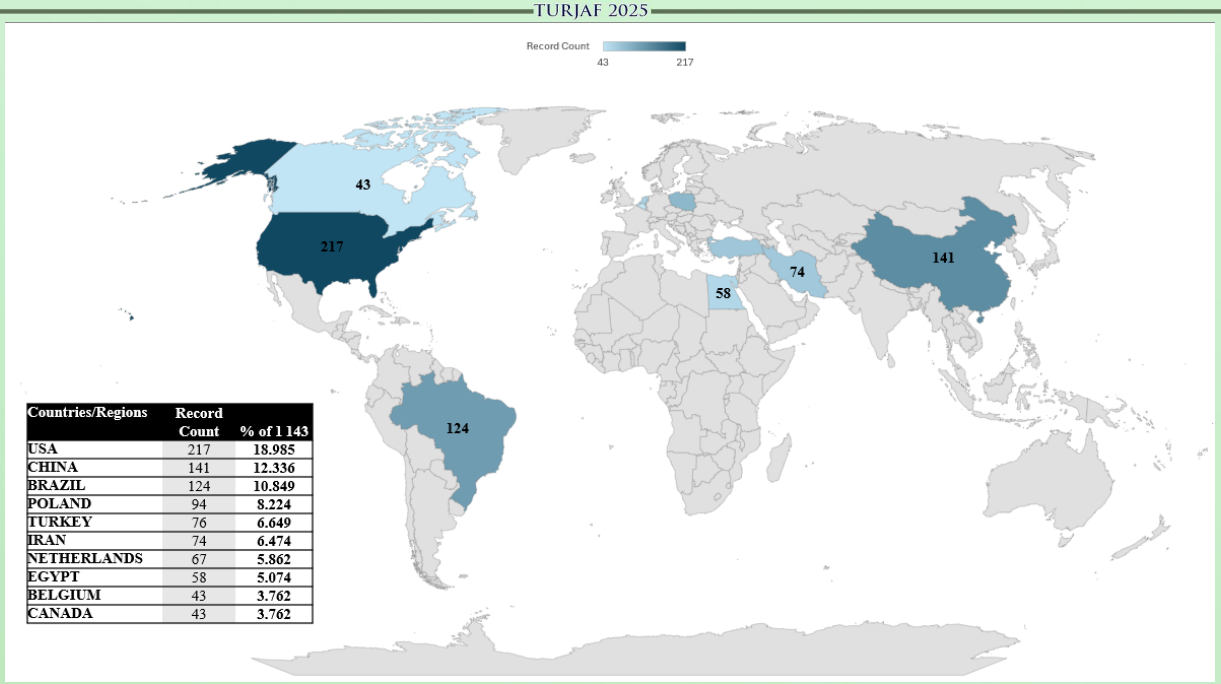
The most productive countries in terms of scientific publications in the field of egg incubation at the broiler level

Figure 2 shows the 10 countries that have published the most papers on research related to the incubation of breeding eggs for the optimization of broiler farming.

On WoS, a total of 1,143 documents are available regarding the work carried out by broiler researchers in the field of egg incubation of broiler breeding females over the last ten years. The USA, China and Brazil stood out through the number of publications they each made in this specific field. Each of these countries has published more than 120 documents. Turkey and Poland follow with more than 70 documents published per country.

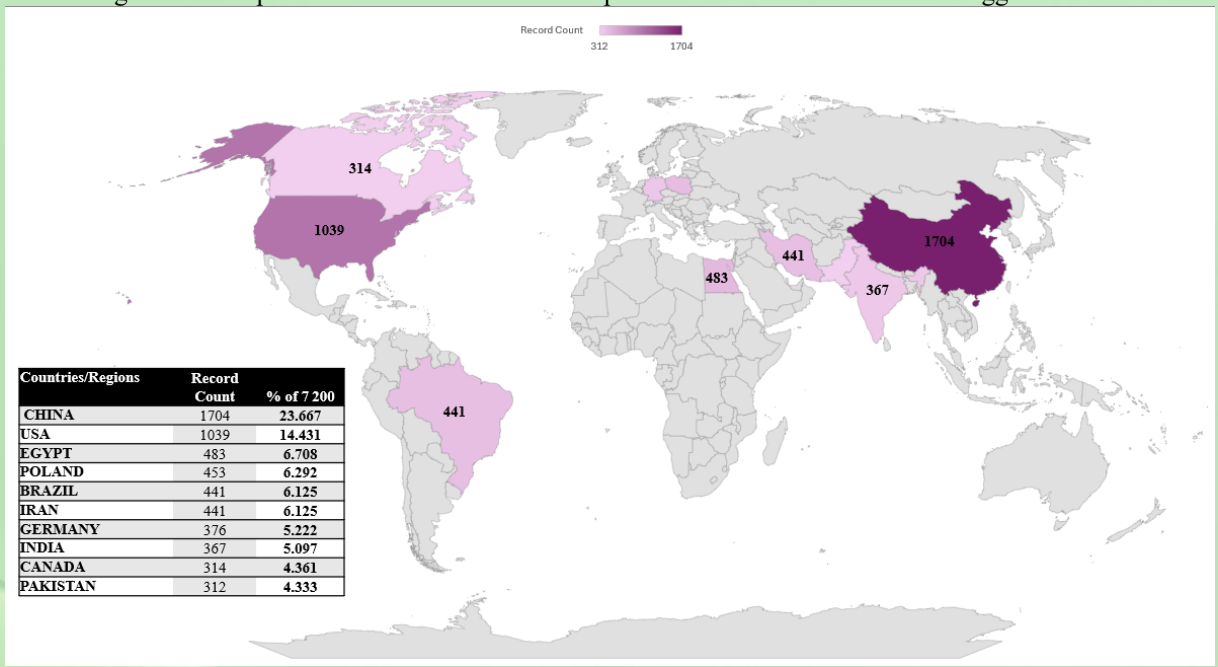
The most productive countries in terms of the production of documents in the broiler nutrition sector

Figure 3 shows the 10 countries that have published the most nutrition papers for the optimization of broiler farming. From 2014 to 2024, the broiler nutrition sector is the area in which researchers have invested the most. Indeed, more than 7,000 documents have been produced worldwide on this theme related to broilers. In this area of research, China, the USA, Egypt, Poland and Brazil alone have produced more than 50% of the available literature in the field of broiler nutrition.



Countries/Regions	Record Count	% of 1 143
USA	217	18.985
CHINA	141	12.336
BRAZIL	124	10.849
POLAND	94	8.224
TURKEY	76	6.649
IRAN	74	6.474
NETHERLANDS	67	5.862
EGYPT	58	5.074
BELGIUM	43	3.762
CANADA	43	3.762

Figure 2. Most productive countries in terms of publications in the field of broiler egg incubation



Countries/Regions	Record Count	% of 7 200
CHINA	1704	23.667
USA	1039	14.431
EGYPT	483	6.708
POLAND	453	6.292
BRAZIL	441	6.125
IRAN	441	6.125
GERMANY	376	5.222
INDIA	367	5.097
CANADA	314	4.361
PAKISTAN	312	4.333

Figure 3. Most productive countries in terms of publications in the field of broiler nutrition

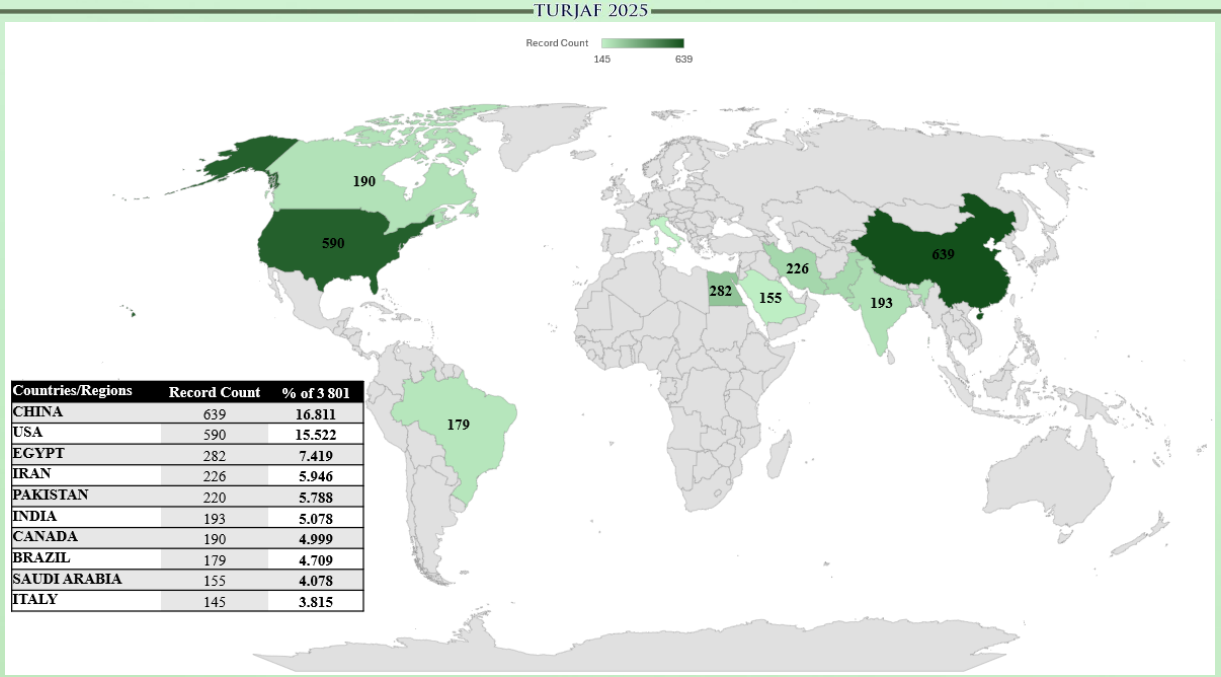
The most productive countries in terms of publications of scientific papers on antibiotics in broiler farming

Figure 4 shows the 10 countries that have published the most papers on the topic of antibiotics in broiler farming. According to the Web of Science database, nearly 4,000 documents are available on research on the use of antibiotics in broiler farming. China, the USA, Egypt, Iran and Pakistan alone have produced more than half of the literature available on the platform. China and the USA produced 639 and 590 documents respectively related to this theme. From this figure, it emerges that Italy is the country to have produced the fewest documents on this theme. Indeed, 145 documents are available to his credit.

The most productive countries in the production of scientific papers related to broiler diseases

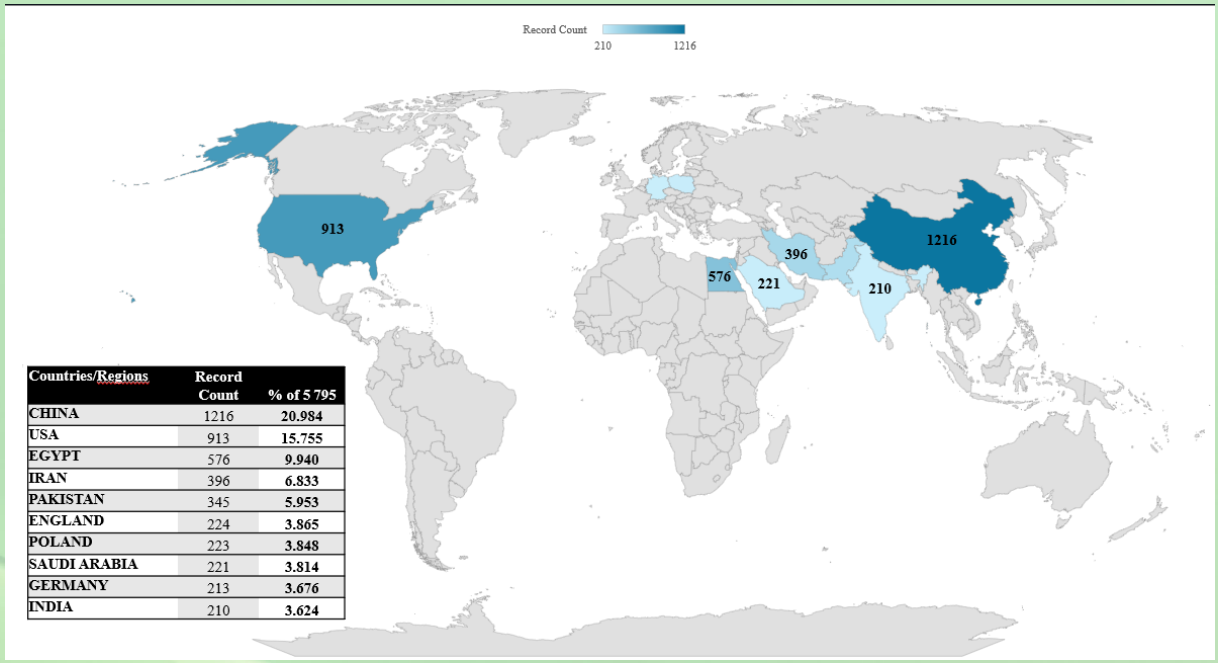
Figure 5 shows the 10 countries that have published the most papers on research on broiler diseases over the past 10 years.

More than 5,000 documents are available on this theme and China, the USA and Egypt are the countries that have produced the most documents. China produced 20% and the USA produced 15% of the literature available on WoS on topics related to diseases in the broiler farming sector.



Countries/Regions	Record Count	% of 3 801
CHINA	639	16.811
USA	590	15.522
EGYPT	282	7.419
IRAN	226	5.946
PAKISTAN	220	5.788
INDIA	193	5.078
CANADA	190	4.999
BRAZIL	179	4.709
SAUDI ARABIA	155	4.078
ITALY	145	3.815

Figure 4. Most productive countries in terms of publications on antibiotics in broiler farming



Countries/Regions	Record Count	% of 5 795
CHINA	1216	20.984
USA	913	15.755
EGYPT	576	9.940
IRAN	396	6.833
PAKISTAN	345	5.953
ENGLAND	224	3.865
POLAND	223	3.848
SAUDI ARABIA	221	3.814
GERMANY	213	3.676
INDIA	210	3.624

Figure 5. Most productive countries in terms of publication of papers on broiler diseases

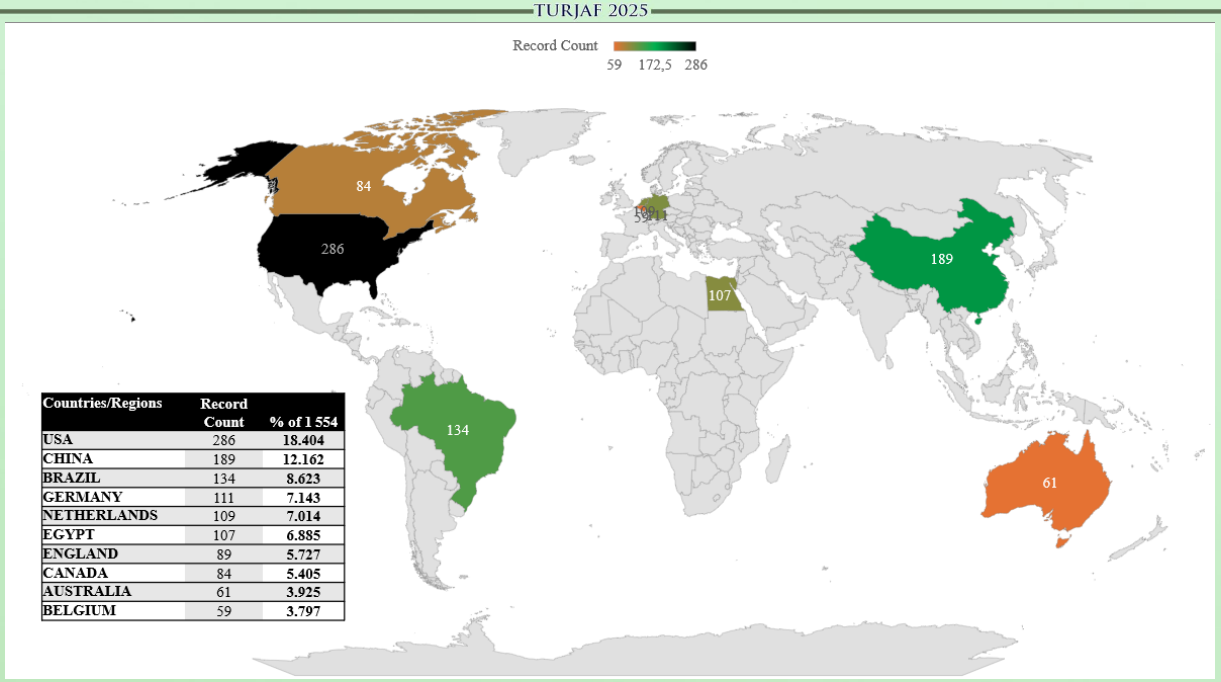
The most productive countries in terms of scientific publications on the theme: behavior, breeding conditions and welfare of broilers in the rearing environment

Figure 6 shows the 10 countries that have published the most scientific papers on research on the behavior, rearing conditions and welfare of broilers in the rearing environment over the past 10 years.

From this figure, it emerges that the USA is also at the top of other countries in terms of the production of scientific documents on the theme, breeding conditions and welfare of broilers in the rearing environment over the last 10 years. Out of 1554 documents, the USA produced 286 documents, or 18% of the total production. China and Brazil produced 189 and 134 papers respectively, i.e. 12.16% and 8.6% of the available literature on the subject, rearing conditions and welfare of broilers in the rearing environment, ranking them second and third after the USA.

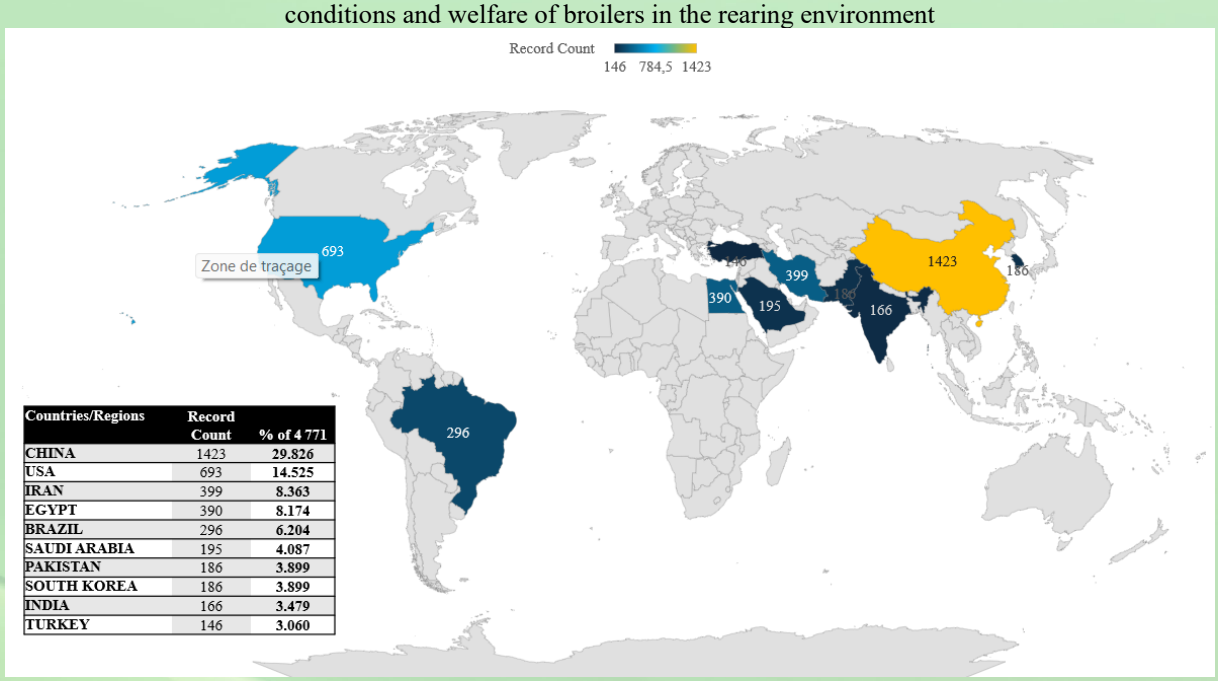
The most productive countries in terms of producing scientific papers on the topic of stress on broilers in livestock farming

Figure 7 shows the 10 countries that have published the most scientific papers on research on the topic of broiler stress in the rearing environment over the past 10 years.



Countries/Regions	Record Count	% of 1 554
USA	286	18.404
CHINA	189	12.162
BRAZIL	134	8.623
GERMANY	111	7.143
NETHERLANDS	109	7.014
EGYPT	107	6.885
ENGLAND	89	5.727
CANADA	84	5.405
AUSTRALIA	61	3.925
BELGIUM	59	3.797

Figure 6. The most productive countries in terms of scientific publications on the theme of the behavior, rearing conditions and welfare of broilers in the rearing environment



Countries/Regions	Record Count	% of 4 771
CHINA	1423	29.826
USA	693	14.525
IRAN	399	8.363
EGYPT	390	8.174
BRAZIL	296	6.204
SAUDI ARABIA	195	4.087
PAKISTAN	186	3.899
SOUTH KOREA	186	3.899
INDIA	166	3.479
TURKEY	146	3.060

Figure 7. Productive countries in terms of scientific publications on stress on broilers in the rearing environment

According to Figure 7, more than 4,500 documents are available on Web of Science about stress on broilers on farms. China, the USA and Iran are the countries that have published more than 50% of the available literature. China alone produced 1,423 documents, or 29.8% of the available documents on stress, putting it at the top of the ranking. In this figure, Turkey occupies the 10th position in the ranking with a total of 146 published documents.

The most productive countries in terms of scientific publications on research carried out on the topic of broiler breeding rooster semen

Figure 8 shows the 10 countries that have published the most scientific papers in terms of research on broiler breeding semen over the past 10 years.

According to Figure 8, there are less than 250 articles available on the topic of semen. It is therefore obvious that this field of research within broiler farming is still quite recent and needs to be further developed. Iran is the country that has produced the most articles on this topic with a total of 75 documents published, i.e. 37.5% of the total production. It is followed by China and the United States, which have produced 29 and 27 documents on this theme respectively.

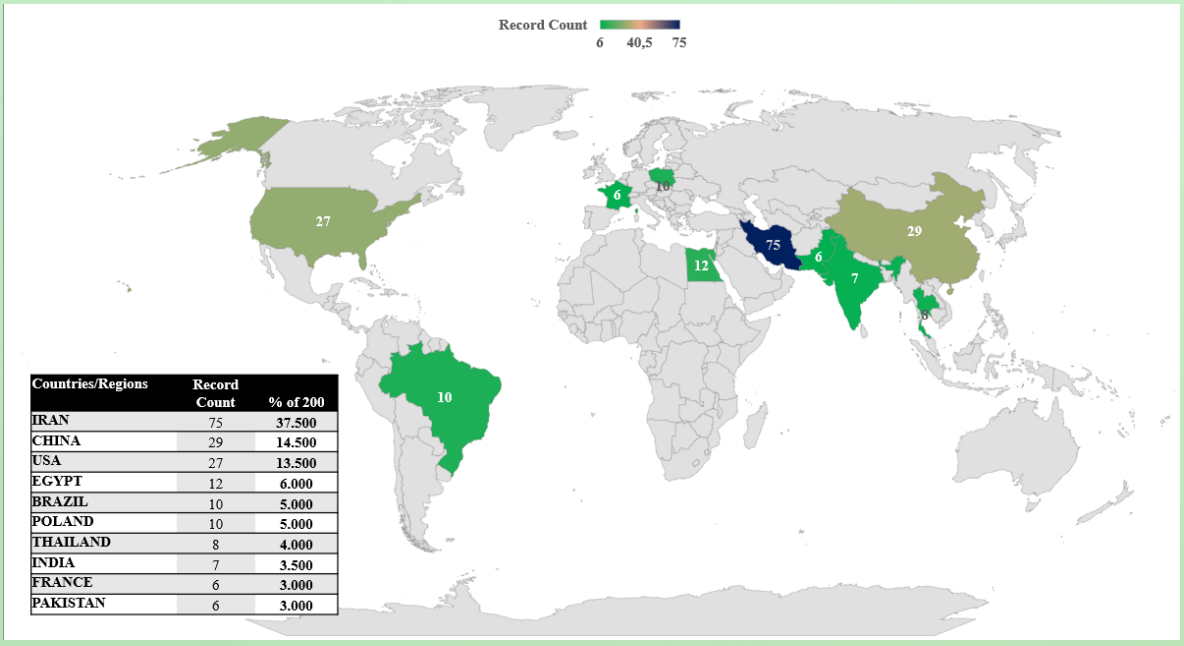
On Web of Science, less than 200 documents related to broiler production in the face of the challenge of climate change are available. This lack of literature underlines the emerging nature of this issue for the poultry industry. Of the 187 documents available, the USA is the country with the most publications with 36 documents to its credit. It is followed by Egypt and Malaysia respectively.

The most productive countries in terms of the production of documents regarding effluent management and greenhouse gas reduction in broiler farming

Figure 10 shows the 10 countries that have published the most scientific research papers on the topics of effluent management and greenhouse gas reduction in broiler farming over the past 10 years.

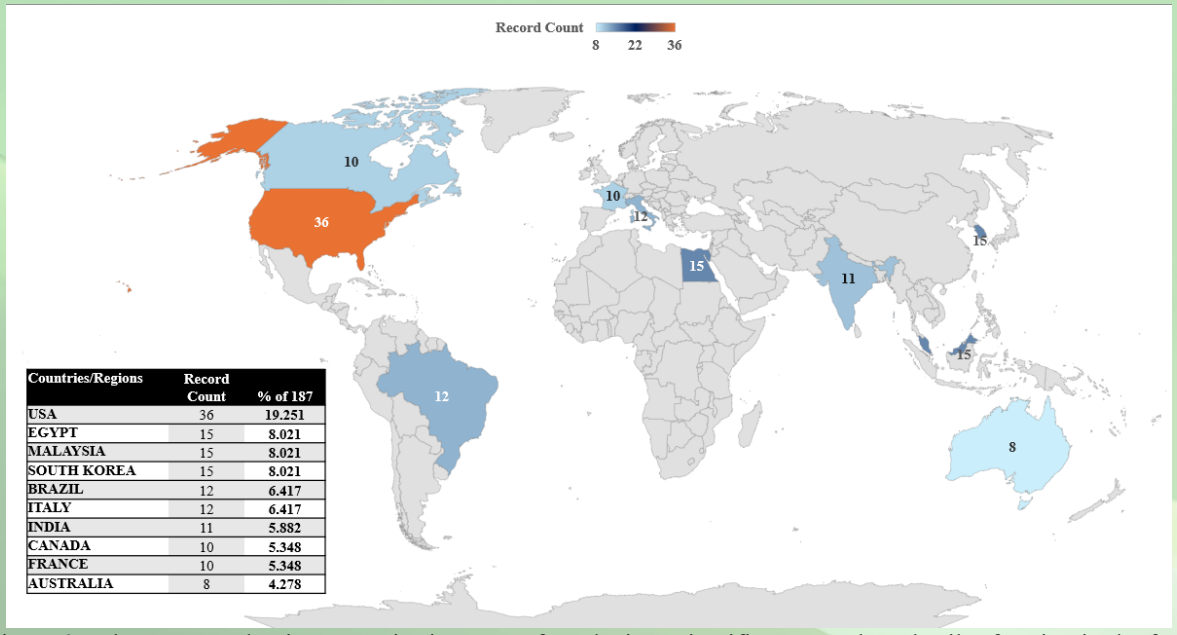
The most productive countries in terms of producing scientific papers about broiler farming in the face of the challenge of climate change

Figure 9 shows the 10 countries that have published the most scientific papers about broiler farming in the face of the challenge of climate change over the past 10 years.



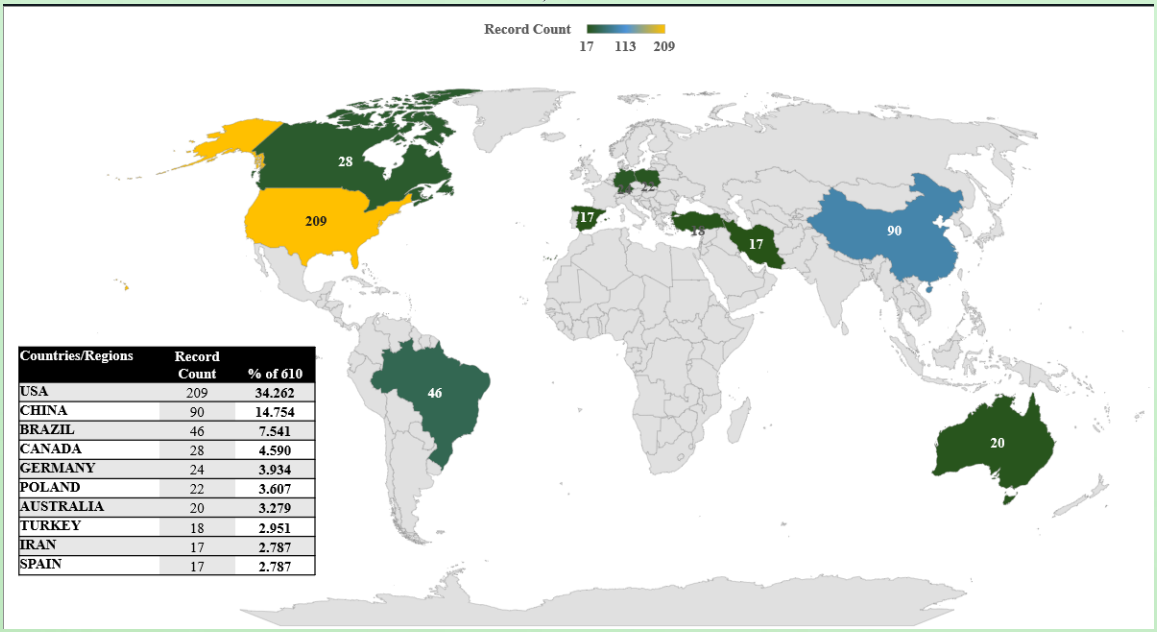
Countries/Regions	Record Count	% of 200
IRAN	75	37.500
CHINA	29	14.500
USA	27	13.500
EGYPT	12	6.000
BRAZIL	10	5.000
POLAND	10	5.000
THAILAND	8	4.000
INDIA	7	3.500
FRANCE	6	3.000
PAKISTAN	6	3.000

Figure 8 : Most productive countries in terms of publication of scientific papers on the topic of broiler breeding cockerel semen



Countries/Regions	Record Count	% of 187
USA	36	19.251
EGYPT	15	8.021
MALAYSIA	15	8.021
SOUTH KOREA	15	8.021
BRAZIL	12	6.417
ITALY	12	6.417
INDIA	11	5.882
CANADA	10	5.348
FRANCE	10	5.348
AUSTRALIA	8	4.278

Figure 9 : The most productive countries in terms of producing scientific papers about broiler farming in the face of the challenge of climate change



Countries/Regions	Record Count	% of 610
USA	209	34.262
CHINA	90	14.754
BRAZIL	46	7.541
CANADA	28	4.590
GERMANY	24	3.934
POLAND	22	3.607
AUSTRALIA	20	3.279
TURKEY	18	2.951
IRAN	17	2.787
SPAIN	17	2.787

Figure 10 : The most productive countries in terms of producing documents on effluent management and greenhouse gas reduction

According to Figure 10, more than 600 papers were published in different journals from 2014 to 2024 in terms of available documents on the topics of manure management and greenhouse gas reduction in broiler farming. Of these 610 documents available, more than a third of the documents, i.e. 209 documents, were published by the United States, followed by China with 90 documents and Brazil with 46 published documents. These three countries have once again produced more than 50% of the available literature.

Results and discussions of the direction of broiler rearing research during 2014 to 2024

Genetics

Research carried out over the last 60 years on broilers through genetic selection has resulted in rapid growth rates, increased meat yield and a significant reduction in the age of slaughter, the amount of feed and the energy required to raise these birds (Bradshaw et al., 2002). Unfortunately, these scientific advances have been achieved without considering the welfare of poultry. Indeed, the rapid growth rate of broilers is closely linked to cardiovascular diseases in poultry, thus causing mortality from sudden death syndrome and ascites, leg disorders and bone deformities leading to leg weakness, lameness and poor locomotor activity (Bessei, 2006).

From 2014 to 2024, research in the field of genetics focused on several key areas, including improving growth and feed efficiency, as well as improving meat quality, this time with poultry welfare in mind (Bailey et al., 2015; Gratta et al., 2019; Hartcher & Lum, 2020). With regard to improving feed efficiency, some research has tried to identify candidate genes, in particular AGK and GTF2I, and QTL (Quantitative Trait Loci) associated with feed efficiency associated with traits such as RFI (Residual Feed Intake) and FCR (Feed Conversion Ratio) (Chen et al., 2021; Shah et al., 2016). Genomic selection studies have been conducted with the goal of improving trait selection practices and accuracy (Sell-Kubiak et al., 2017).

Since muscular myopathies (white streaks and woody breasts) have been observed in broilers in recent years, various studies were carried out between 2014 and 2024 to understand and limit their appearance in broiler meat. At the genetic level, the studies conducted have made it possible to explore the genetic basis of myopathies in order to identify the molecular mechanisms involved (Gratta et al., 2019; Lake et al., 2021). In addition, as animal welfare is also a topical issue, research in the field of genetics related to broilers has examined the negative impacts of intensive selection (locomotor problems, metabolic diseases, etc.) on broilers with the aim of finding palliative solutions (Hocking, 2014). Finally, research has also been carried out on genetic diversity and antimicrobial resistance in certain pathogens, including *Campylobacter*and*Salmonella* with the sole aim of controlling the epidemiology of these bacteria while developing strategies to better control infections (Vidal et al., 2016; Ramires et al., 2020; Mughini-Gras et al., 2021).

Egg Incubation

Egg incubation has also been an area in which researchers have had to conduct studies over the past ten years. Research has focused on optimizing environmental conditions to improve embryo development, chick quality, post-hatch growth and bird welfare. Studies have explored the effect of incubation temperature on embryo

development. It has been noted that a temperature of 37.8°C is the optimal temperature to ensure perfect development of broiler chick embryos. Also, slight temperature variations could also allow better embryo development. Other studies have shown that temperatures that are too low significantly slow down embryonic development, while temperatures that are too high speed up embryonic development. These temperature variations can cause many malformations, abnormalities in the legs and can affect the development of long bones in chicks (Afsarian et al., 2018; Maatjens et al., 2016; Oznurlu et al., 2016; Wijnen et al., 2020).

At the same time, exposure to light during incubation has been the subject of research by some researchers to study the impact of this process on the metabolism, muscle growth and immunity of the immune system. Chicks. It has been noted that light, whether red, white or blue in color, does not affect embryonic mortality, hatching time, hatching and even less the quality of the chicks obtained. However, exposure of eggs to light could have a negative effect on the immunity and energy metabolism of broiler embryos (Archer, 2017; X. Li et al., 2021). In addition, research on the in ovo injection of nutrients, amino acids or prebiotics during incubation has made it possible to understand the positive effect of this practice on the development of broiler embryos. This practice also serves to strengthen and improve the expression of genes related to growth (Elnesr et al., 2019; Elwan et al., 2019; Stadnicka et al., 2020).

In addition, much other research has been done on egg storage time, types of incubators, moisture management, and factors (age of the parental flock, ventilation and carbon dioxide concentration**)** that can affect chick hatching (Şahan et al., 2014; Damaziak et al., 2018; Okur et al., 2018; H.T. Meteyake et al., 2020; Mesquita et al., 2021; Biesek et al., 2023).

Broiler Nutrition, Growth Performance and Meat Quality

In terms of the direction of research in this specific area, it should be noted that the studies have been directed towards several key areas, the main ones being the optimization of gut health, growth performance and meat quality through the strategic use of feed additives. These various studies have made it possible to understand that feed additives such as probiotics, phytogenics and exogenous enzymes (xylanase, glucanase and protease) have beneficial effects on the intestinal health of broilers (Cho et al., 2014; Sadeghi et al., 2015; Hafeez et al., 2016; Munyaka et al., 2016; Amerah et al., 2017). They have a positive effect on the intestinal microflora, the digestibility of nutrients and participate in the reduction of potentially pathogenic enterobacteriaceae (Munyaka et al., 2016). According to studies, phytogenics containing essential oils based on thyme and star anise in particular optimize the weight gain and feed conversion ratio of chickens, while reducing lipid oxidation and improving the meat quality of broilers (Starčević et al., 2015). Similar results have also been obtained by substituting phytogenics by the enzyme xylanase (W.-C. Liu & Kim, 2017).

At the same time, other studies have shown that the reduction of crude protein content in broiler feeds combined with an amino acid profile can optimize the sustainability of broiler production without compromising their performance (Belloir et al., 2017). On the one hand, the use of blubber from black soldier fly larvae (*Hermetia illucens*) in broiler feeding have also been the subject of research (Cullere et al., 2019).

On the other hand, in order to find an alternative to the soy proteins used in the feed of broilers, research has been carried out to analyze the impact of the use of insect proteins on the environment, on the growth performance of broilers as well as on the quality of broiler meat (Pieterse et al., 2019; Vauterin et al., 2021). Finally, research has focused on the factors contributing to myopathies such as gender, diet and genetics, while focusing on antioxidant strategies to be implemented to limit muscle degeneration (Trocino et al., 2015; Radaelli et al., 2017).

Antibiotics

Since the ban on the use of antibiotics as growth promoters in animal feed (PGAs) by the European Union in 2006 (Castanon, 2007), the poultry industry has faced enormous challenges. Since then, a lot of research has been initiated with the aim of looking for palliative solutions to the use of antibiotics in the poultry industry. Research carried out over the last decades (2014-2024) has also been oriented in this direction, and studies on organic acids as feed additives that can be used to improve the performance of broilers have been carried out (Polycarpo et al., 2017; Mehdi et al., 2018).

Other studies on probiotics include *Bacillus subtilis* and *Saccharomyces cerevisiae* as substitutes for antibiotics for the improvement of growth performance and gut health of broilers were also carried out (T. He et al., 2019). Similarly, studies on phytogenics have been carried out (Abudabos et al., 2016) given their antioxidant status and the immunity it grants to poultry when incorporated into their feed. Research on essential oils has also been carried out with the aim of evaluating their antimicrobial activity as a potential substitute for antibiotics (Y. Liu et al., 2017; Fancher et al., 2020).

Other studies have focused on assessing the economic and zootechnical impact of whether or not the use of PGAs in broiler feed is discontinued, while monitoring antibiotic resistance by pathogens (Maria Cardinal et al., 2019; Roth et al., 2019). On the environmental side, the studies carried out focused on the persistence of antibiotics in soil and slurry and their ability to pollute the environment (Ho et al., 2014; L.-Y. He et al., 2014; Berendsen et al., 2018).

Diseases

Apart from genetics, nutrition, and improving the quality of meat, research over the last ten years in the field of broiler breeding has also been oriented towards the field of avian diseases. These studies were conducted with the goal of understanding, preventing and controlling infectious and metabolic diseases that can occur in broiler farming. Some research has focused on Gumboro disease, infectious bronchitis, Newcastle disease, necrotic enteritis and woody chest disease.

As far as Gumboro disease is concerned, studies have categorized viral strains, evaluated the effectiveness of vaccines and understood the evolution of the said virus (Kurukulasuriya et al., 2017; Yilmaz et al., 2019). Research focused on Newcastle disease has been used to optimize vaccination regimens and reduce viral shedding through the use of inactivated vaccines (Sattar et al., 2016; Sultan et al., 2021). For research related to infectious bronchitis, the latter focused on the molecular genotyping of the infectious bronchitis virus as well as on the comparison of the pathogenicity of the available strains (Chacón et al., 2014; Haji-Abdolvahab et al., 2019).

Studies conducted on necrotic enteritis have made it possible to measure the occurrence of this disease and production performance in broiler farms (Silva et al., 2015; Kaldhusdal et al., 2016). Other studies have examined the role of *Clostridium perfringens* in necrotic enteritis and also seek to understand the factors that can predispose to this disease in broilers (Caekebeke et al., 2021). Woody chest disease, on the other hand, has been genomic-studied, to identify the genes and metabolic processes involved (Papah et al., 2018; Brothers et al., 2019).

Behavior, rearing conditions and welfare of broilers

Research from 2014 to 2024 also focused on improving broiler farming conditions with a view to promoting natural behaviors and reducing the stress experienced by poultry. A few studies have explored the effect of stocking density on broiler behavior (H. Ma et al., 2020; Van Der Eijk et al., 2022). These studies have made it possible to understand that low density can help reduce stress on birds and encourage locomotion and foraging behaviors while optimizing meat quality.

In order to encourage positive behaviour while reducing heat stress, environmental conditions (temperature, humidity, light, noise, etc.) as well as the enrichment of the broilers' environment by setting up perches, pecking objects and organic bedding were studied (Yngvesson et al., 2017; Bergmann et al., 2017; Çavuşoğlu & Petek, 2019; Lucena et al., 2020; Fidan et al., 2020; Bai et al., 2023).

Other studies have been conducted to understand how specific behaviors such as grooming, resting, feeding and others may be affected by rearing conditions in order to serve as an indicator of well-being (Bergmann et al., 2017; Riber et al., 2021). Also with the aim of collecting accurate information on the behavior of poultry, research has been carried out using new technologies such as computer vision and the use of electronic sensors (Lucena et al., 2020; N. Li et al., 2020; Bai et al., 2023; G. Li et al., 2023). Finally, other research has examined the impact of transport and the use of electronic feeding systems on stress and feed efficiency (Fu et al., 2022; Werner et al., 2023).

Stress

Given the major damage caused by heat stress in the poultry industry, research from 2014 to 2024 also focused on the subject. Research on stress in broiler rearing has focused on identifying and mitigating major stressors such as heat stress, density stress and immunological stress. As far as heat stress is concerned, because broilers do not have a sweat gland and have a high metabolism and more or less thick plumage, they are particularly vulnerable to this type of stress (Z. H. Song et al., 2018).

Studies have therefore explored the impacts of heat stress on the intestinal morphology, microbiota and meat quality of broilers and have evaluated feeding strategies based on the use of prebiotics such as mannan-oligosaccharides (MOS) (Cheng et al., 2019), probiotics (Al-Fataftah & Abdelqader, 2014; J. Song et al., 2014), postbiotics (Humam et al., 2019), curcumin (J. F. Zhang et al., 2018), resveratol (C. Zhang et al., 2017), betaine (S. He et al., 2015; W. Liu et al., 2019) to strengthen antioxidant status and the intestinal barrier to mitigate the negative effects of heat stress on birds. Research on immunological stress has been addressed through the analysis of immune responses and the use of immunostimulants such as astragalus polysaccharides (APS) (L. Liu et al., 2015).

As for the stress related to stocking density, studies have analyzed the effects of stocking density on the growth and welfare of broilers while taking into account interactions with heat stress (Cengiz et al., 2015; Goo et al., 2019). Since heat stress also affects meat quality, causing color changes, increased water loss and changes in muscle metabolism, studies are seeking to understand the molecular mechanisms by which heat stress deteriorates meat quality while identifying strategies that can help mitigate these effects (Lu et al., 2017; Awad et al., 2020; B. Ma et al., 2021).

Finally, genetics tries to identify the differences in resistance to existing heat stress between different breeds and strains of broilers. (Sahin et al., 2016; Y. Xu et al., 2018; Awad et al., 2020). In addition, genetic selection studies are seeking to identify genetic markers associated with stress tolerance in order to use them to optimize stress resistance in broilers (Rimoldi et al., 2015).

Sperm

The quality of the sperm of breeding roosters plays a vital role in broiler farming, as it directly impacts the fertility, hatching rate and productivity of the chickens. Given its importance, research from 2014 to 2024 was much more focused on optimizing sperm quality by using feed additives in the diet of breeding roosters. Other research has investigated the environmental and biological factors that can negatively impact on the fertility of breeding animals. As dietary supplements, it was the use of ellagic acid (Najafi et al., 2019), polyunsaturated fatty acids (PUFAs) (Teymouri Zadeh et al., 2020), organic selenium and selenium nanoparticles (SeNPS) (Asghari-Moghadam & Mehri, 2024). These studies show that these feed additives optimize the viability, motility and antioxidant parameters of the sperm of breeding roosters while reducing oxidative damage (Abbaspour et al., 2020).

In addition, studies have conducted research on the effect of bacteria on sperm motility. Only Escherichia coli bacteria producing extended-spectrum beta-lactamases (ESBL) were considered. From these studies, it appears that the impact that these bacteria have on the motility of the sperm of breeding roosters varies according to the strains (Mezhoud et al., 2015). In addition, studies on the intake of noisy protein (CP) in the diet of breeding roosters have also been performed. This research has shown that a moderate reduction in crude protein levels in the diet of breeding roosters does not really affect sperm quality. However, it has been noted that an increase in the level of crude protein in the diet of breeding roosters at the end of the cycle can improve their fertility (Graaf et al., 2019).

Climate change

Climate change has a direct impact on poultry production, including bird growth, egg production and the overall health of animals. Given heat waves, a decrease in feed consumption by animals as well as an increase in the mortality rate of the flock can thus cause severe economic losses to the poultry industry (Mn et al., 2024). Over the past 10 years they have focused their studies on the search for strategies that can allow birds to adapt to climate change. On the other hand, researchers have conducted studies to develop strategies that can mitigate the effects of climate change on poultry for much more sustainable production.

For adaptation strategies, the researchers focused on optimizing housing systems. The results of these studies revealed that improving broiler housing systems would help maintain an optimal thermal environment for good production. For this purpose, efficient ventilation, efficient cooling mechanisms and the most adequate thermal insulation should be added to broiler housing (Mn et al., 2024; Oke et al., 2024). Other studies have focused on optimizing diets, including supplementing broiler feed with antioxidants to reduce the effects of heat stress on birds. At the same time, the use of animal fat to improve energy intake in poultry feed has also been the subject of research (Kpomasse et al., 2021; Mn et al., 2024). Finally, research in genetic selection tends to select poultry that can withstand heat and resist diseases (Kumar et al., 2021).

About strategies to mitigate the effects of climate change on broiler production, research has been directed towards climate modelling and direct cooling systems to assess and mitigate the impact of climate change on production costs, performance and poultry welfare. The objective of these studies is to anticipate the challenges posed by climate change on the poultry industry in order to adapt appropriate management practices (Lourençoni et al., 2019; Mn et al., 2024; Oke et al., 2024).

Effluent management and greenhouse gas reduction

To reduce the environmental impact of livestock farming, the management of livestock manure is essential. As a result, for the preservation of the environment and to better use the effluents from broiler farming, several studies have been carried out over the last ten years. Some research has focused on studying the composition of manure according to age and the diets to which poultry have been subjected in order to understand how feed may influence manure quality and ammonia emissions (Van Emous et al., 2019). A significant portion of the research conducted over the past decade has been aimed at reducing ammonia emissions from broiler manure by manipulating the amount of crude protein in the feed and using urease inhibitors.

Other research studies manure in order to use it as an agricultural amendment to optimize soil fertility (Lima et al., 2014; Keskinen et al., 2019). The composting of broiler manure was also studied with a focus on monitoring antibiotic residues in order to understand its impact on antibiotic degradation and the reduction of environmental risks (Wang et al., 2022; X. Xu et al., 2022). A study compared four different types of broiler manure treatment, including storage, composting, anaerobic digestion and biochar production, to assess greenhouse gas emissions. The study shows that anaerobic digestion and pyrolysis appear to be the most promising treatments for reducing greenhouse gases in the environment and producing useful resources such as biogas or biochar (Kreidenweis et al., 2021). Further studies have shown that adding substances such as magnesium sulphate (MgSO4.7H2O) to bedding is an effective technique for reducing ammonia (NH3) and nitrous oxide ($N_{2O)\ in\ poultry\ houses}$ (Pereira et al., 2019).

Conclusion

This study analyzed the direction of research carried out in broiler farming over the last ten years using the Web of Science database. This analysis made it possible to understand that many studies have been carried out on key themes such as genetics, egg incubation, nutrition, antibiotic use, avian diseases, bird behavior and the level of stress suffered by broilers in the farming environment. On the other hand, about topics relating to sperm quality, climate change, effluent management and the reduction of greenhouse gases, the analysis revealed that these themes are still little explored. It is therefore obvious that future research will focus much more on these topics regarding broiler farming while highlighting bird welfare and meat quality. However, the overall goal of the 2014 to 2024 research on broilers was to promote farming practices that optimize animal welfare, natural behaviors, and productivity, considering the complex interactions between the environment, genetics, and management practices.

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A Natural Solution Against Fish Oil Oxidation: The Antioxidant Effect of Satureja montana Essential Oil

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Abstract

Fish oil, due to its high content of polyunsaturated fatty acids (PUFA), is extremely sensitive to oxidation, which can negatively affect its nutritional quality and shelf life. In this study, the effects of Satureja montana (SMont EO) essential oil on fish oil oxidation were investigated. Within the scope of the experiment, different concentrations (100, 200, 400, 800 ppm) of Satureja montana essential oil were added to fish oils, and the commercial antioxidant BHT (200 ppm) was used as a positive control. The experimental groups were subjected to accelerated oxidation for 96 hours under 55°C temperature, 70% humidity, and 7000 lux illumination. Oxidation levels were determined by measuring peroxide value (PV) and malondialdehyde (MDA), and the obtained data were statistically analyzed using one-way ANOVA and Tukey's test. According to the GC-MS analysis results, Satureja montana essential oil contains the highest amounts of carvacrol (42.62%), γ-terpinene (12.44%), and p-cymene (14.09%). It has been reported in the literature that carvacrol is a strong free radical scavenger, γ-terpinene can prevent lipid peroxidation, and p-cymene plays an important role in combating oxidative stress. According to the peroxide value measurements, it was determined that the group containing 400 ppm Satureja montana oil had the lowest oxidation level. The peroxide value of the 400 ppm dose was determined to be 16.08 meq O_2/kg, which is similar to the commercial antioxidant BHT (25.48 meq O_2/kg). MDA levels were also measured at the lowest level in the 400 ppm essential oil group, but a slight increase was observed at the 800 ppm dose. The results indicate that Satureja montana essential oil is an effective natural antioxidant in preventing fish oil oxidation. It has been determined that a concentration of 400 ppm provides the best oxidative stability. Compared to the commercial antioxidant BHT, Satureja montana essential oil provided a similar level of oxidative protection, therefore it can be considered as an alternative to synthetic antioxidants in aquaculture feeds.

Key Words: *Fish oil oxidation, Satureja montana essential oil, Natural antioxidants, Peroxide value, Lipid peroxidation*

Introduction

Aquaculture is an essential sector for fulfilling the animal protein requirements of the swiftly expanding global population (Nasopoulou & Zabetakis, 2012). In this sector, fish oil provides a crucial nutritional source owing to its elevated quantity of polyunsaturated fatty acids (PUFAs). Omega-3 fatty acids (EPA and DHA) are known for their beneficial benefits on human health and are deemed critical components of feeding protocols in aquaculture (Harris, 2004; Rizliya & Mendis, 2013). Fish oil is particularly sensitive to oxidation because of its elevated levels of polyunsaturated fatty acids (Frankel, 1984).

Lipid oxidation results in the degradation of fat content via free radicals, leading to diminished food quality and modifications in flavor and odor (Shahidi & Zhong, 2010). This procedure reduces the shelf life of fish oil-containing nutrition and adversely impacts growth performance and feed efficiency in fish (Oliva-Teles et al., 2022).

Therefore, the use of antioxidants is crucial in order to avert the oxidation of fish oil. A common antioxidant in current commercial products is the synthetic compound butylated hydroxytoluene (BHT). Nevertheless, research indicates that certain synthetic antioxidants may exhibit toxic side effects and potentially detrimental effects on human and fish health over time (Wang et al., 2021).

This circumstance requires the investigation of natural antioxidant sources and the formulation of alternative treatments (Gulcin, 2020; Kesbiç, 2023). Essential oils, phenolic compounds, and terpenoids are prominent natural antioxidants due to their composition (Ben Hsouna et al., 2017). This study assessed the potential preventive effect of Satureja montana essential oil (SMont EO) on the oxidation of fish oil. SMont EO exhibits antioxidant and antibacterial properties thanks to its elevated carvacrol concentration.

(Trifan et al., 2015).

This research aims to clarify the potential advantages of including natural antioxidants into aquaculture feeds and to empirically validate the efficacy of Satureja montana essential oil as a substitute for synthetic antioxidants.

Materials and Methods

The SMont EO utilized in the study was procured from a commercial source, and the volatile component composition of the product was qualitatively analyzed using GC/MS (Kesbiç 2019).
The objective is to examine the efficacy of various concentrations of SMont EO (100 ppm, 200 ppm, 400 ppm, and 800 ppm) in inhibiting the oxidation of fish oil. To achieve this objective, fish oils from various experimental groups were subjected to accelerated oxidation conditions, and their impacts on oxidative stability were assessed by quantifying the peroxide value (PV) and malondialdehyde (MDA) levels. The study employed commercial antioxidant BHT at 200 ppm (BHT200) as the positive control, while fish oil without additions served as the negative control. To facilitate accurate comparisons and assess the quality of the oil utilized in the study, the peroxide (Kesbiç, 2023) and MDA (Okhawa et al., 1979) levels of the fresh fish oil were measured.
The rapid oxidation study was conducted under conditions of temperature, humidity, and light that would trigger oxidation. The prepared experimental groups were subjected to an accelerated oxidation process for 4 days at a temperature of 55.0±0.5°C, in a 70% humid atmosphere, and under 7000 lux illumination. Subsequently, peroxide and MDA measurements were conducted.

Results and Discussion

This study studied the effects of Satureja montana essential oil on the oxidation of fish oil and examined its antioxidant activity. The GC-MS analysis identified the three main components of the essential oil as carvacrol (42.62%), γ-terpinene (12.44%), and p-cymene (14.09%). Carvacrol has been identified as a potent free radical scavenger owing to its phenolic structure, and prior research has demonstrated its substantial effect in inhibiting lipid peroxidation (Trifan et al., 2015).
This molecule, extensively utilized as a natural antioxidant in food preservation, has also been examined as an effective agent against oxidative stress (Burt, 2004). γ-Terpinene is known for its capacity to neutralize highly reactive oxygen species (ROS), and it has been demonstrated that this characteristic enhances the oxidative stability of oils by inhibiting lipid peroxidation (Ruberto & Baratta, 2000). The p-Cymene molecule, owing to its lipophilic nature, demonstrates a protective impact on cellular membranes and inhibits oxidative degradation by disrupting free radical chain reactions (Gülçin et al., 2012). The existence of these components scientifically validates the antioxidant capacity of Satureja montana essential oil and demonstrates that the observed antioxidant activity in the study is grounded in its biochemical composition.
The peroxide values (PV) assessed across several experimental groups have yielded significant insights into the oxidative stability of the fish oil samples (Table 1).
The peroxide value in the control group was measured at 75.48 meq O_2/kg, considerably higher than that of fresh fish oil. This means that oxidation is advancing and lipid peroxidation has increased markedly. The group that administered the commercial antioxidant BHT (200 ppm) exhibits a peroxide value of 25.48 meq O_2/kg and demonstrates comparable antioxidant efficacy to the groups utilizing essential oils. The application of Satureja montana essential oil has resulted in a notable reduction in peroxide values. At a concentration of 100 ppm, the peroxide value was measured at 26.59 meq O_2/kg; at 200 ppm, it was 18.87 meq O_2/kg; and at 400 ppm, it was 16.08 meq O_2/kg. The peroxide value was lowest at a dosage of 400 ppm, indicating that this concentration provides the most efficient oxidative protection. At a concentration of 800 ppm, the peroxide value measured 22.41 meq O_2/kg, suggesting that volatile oil may demonstrate pro-oxidant activity at elevated levels. Research indicates that a concentration of 400 ppm of essential oil ensures adequate oxidative stability, however elevated doses may result in erratic oxidative effects (Kesbiç, 2023).
The study examined MDA levels to assess the evolution of oxidative stress, providing as a quantitative indication of lipid peroxidation. The control group showed the highest levels of MDA, reflecting the highest level of oxidation. The group supplied 200 ppm BHT and those obtaining 400 ppm Satureja montana essential oil exhibited the lowest MDA levels. This condition suggests that the antioxidant efficacy of the essential oil is comparable to that of BHT. It has been shown that MDA levels increased at the 800 ppm dosage, corroborating the concept that elevated doses may demonstrate a pro-oxidant impact. Some research in the literature indicate that excessive antioxidant use can negatively impact specific oxidative stress conditions (Wang et al., 2011).
This study's results demonstrate that Satureja montana essential oil serves as an excellent natural antioxidant in inhibiting the oxidative degradation of fish oil. The lowest values of peroxide and MDA were observed, particularly at a concentration of 400 ppm. In comparison to the commercial antioxidant BHT, Satureja montana essential oil offered an equivalent level of oxidative protection, suggesting that natural antioxidants may serve as viable alternatives to manufactured ones. Natural antioxidants present a substantial alternative to the deleterious effects of synthetic chemicals and confer benefits for food safety. In conclusion, Satureja montana essential oil demonstrates potent antioxidant activities attributed to its constituents carvacrol, γ-terpinene, and p-cymene, which are thought to augment oxidative stability. Research indicates that plant essential oils abundant in phenolic

components may serve as natural antioxidants in aquaculture diets. Further research is required to examine the long-term stability of these natural components under varying temperature and storage conditions.

Table 1. Peroxide values (meq O_2/kg) of experimental groups after rapid oxidation procces.

Experimental Groups	N	Mean	Standart Deviation	Grouping Information	
BHT 200	3	25,480	1,426	B	
Control	3	75,48	2,94	A	
Fresh Fish Oil	3	5,212	1,091	E	
SMont EO0.1	3	26,595	1,308	B	
SMont EO0.2	3	18,876	1,016	CD	
SMont EO0.4	3	16,081	1,155	D	
SMont EO0.8	3	22,410	1,384	BC	
Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
Control - BHT200	50,00	1,31	(45,54; 54,46)	38,31	0,000
Fresh Fish O - BHT200	-20,27	1,31	(-24,72; -15,81)	-15,53	0,000
SMont EO0.1 - BHT200	1,12	1,31	(-3,34; 5,57)	0,85	0,974
SMont EO0.2 - BHT200	-6,60	1,31	(-11,06; -2,15)	-5,06	0,003
SMont EO0.4 - BHT200	-9,40	1,31	(-13,86; -4,94)	-7,20	0,000
SMont EO0.8 - BHT200	-3,07	1,31	(-7,53; 1,39)	-2,35	0,286
Fresh Fish O - Control	-70,27	1,31	(-74,72; -65,81)	-53,84	0,000
SMont EO0.1 - Control	-48,88	1,31	(-53,34; -44,43)	-37,46	0,000
SMont EO0.2 - Control	-56,60	1,31	(-61,06; -52,14)	-43,37	0,000
SMont EO0.4 - Control	-59,40	1,31	(-63,85; -54,94)	-45,51	0,000
SMont EO0.8 - Control	-53,07	1,31	(-57,53; -48,61)	-40,66	0,000
SMont EO0.1 - Fresh Fish O	21,38	1,31	(16,93; 25,84)	16,38	0,000
SMont EO0.2 - Fresh Fish O	13,66	1,31	(9,21; 18,12)	10,47	0,000
SMont EO0.4 - Fresh Fish O	10,87	1,31	(6,41; 15,33)	8,33	0,000
SMont EO0.8 - Fresh Fish O	17,20	1,31	(12,74; 21,65)	13,18	0,000
SMont EO0.2 - SMont EO0.1	-7,72	1,31	(-12,18; -3,26)	-5,91	0,001
SMont EO0.4 - SMont EO0.1	-10,51	1,31	(-14,97; -6,06)	-8,06	0,000
SMont EO0.8 - SMont EO0.1	-4,19	1,31	(-8,64; 0,27)	-3,21	0,072
SMont EO0.4 - SMont EO0.2	-2,80	1,31	(-7,25; 1,66)	-2,14	0,382
SMont EO0.8 - SMont EO0.2	3,53	1,31	(-0,92; 7,99)	2,71	0,167
SMont EO0.8 - SMont EO0.4	6,33	1,31	(1,87; 10,79)	4,85	0,004

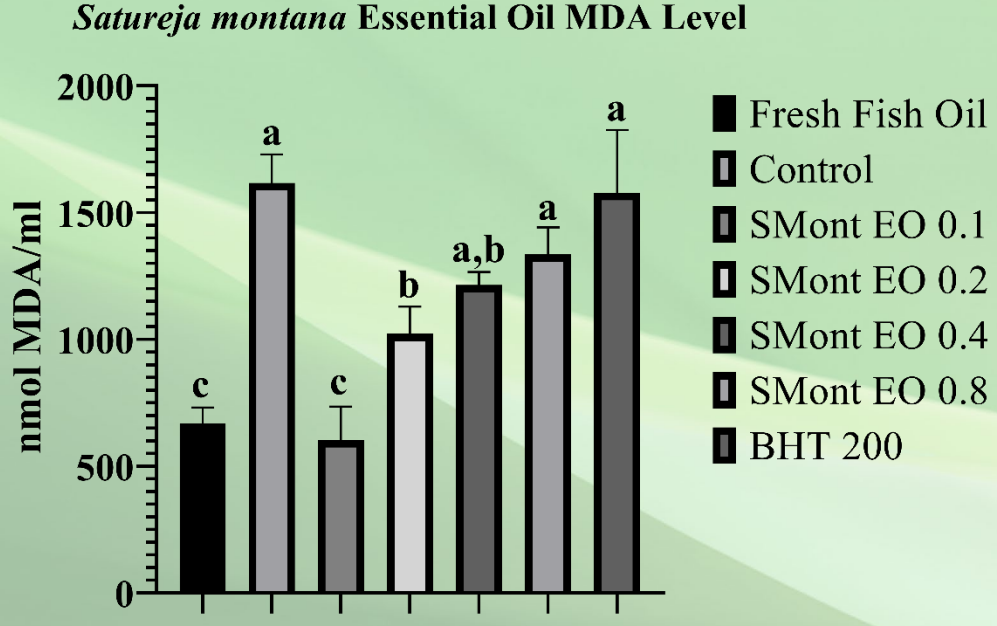


Figure 1. MDA levels of experimental fish oils after oxidation.

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Agricultural Carbon Footprint, Environmental Pressures, and Mitigation Policies within the Framework of the Paris Climate Agreement: A Comparative Analysis of Turkey and the European Union

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Abstract

The agricultural sector, while a vital component of economic production and food security, is also one of the major contributors to global greenhouse gas emissions. Following the ratification of the Paris Climate Agreement, the environmental impacts of agriculture especially its carbon footprint have become critical points of analysis and policymaking. This review compares the carbon emissions, environmental pressures, and mitigation policies in agriculture between the European Union (EU) and Turkey.

The concept of a carbon footprint encompasses emissions of methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2) from agricultural activities such as livestock, fertilizer use, land cultivation, and irrigation. EU member states have taken significant steps toward reducing these emissions in alignment with the Paris Agreement, notably through the Green Deal, reform of the Common Agricultural Policy (CAP), and carbon taxation. In contrast, Turkey, although it ratified the Paris Agreement in 2021, lacks an integrated national strategy for reducing agricultural emissions. Nevertheless, some promising pilot projects and organic agriculture promotion initiatives exist across regions.

This paper synthesizes findings from over 75 academic studies and official policy reports. The results demonstrate that the EU possesses a more mature framework in terms of monitoring, reporting, and carbon market instruments. For Turkey to meet its climate targets and align with EU standards, substantial investments in regulatory adaptation, climate financing mechanisms, and digital agricultural infrastructure are needed.

Ultimately, the study concludes that addressing the environmental impact of agriculture requires both regional collaboration and institutional capacity building. Enhanced cooperation between the EU and Turkey in climate-smart agriculture and emission reduction strategies would yield significant benefits for both environmental sustainability and economic competitiveness in the region.

Key Words: *Carbon Footprint, Agriculture, Emissions, Türkiye, EU Union*

Paris İklim Anlaşması Çerçevesinde Tarımsal Karbon Ayak İzi, Çevresel Baskılar ve Azaltım Politikaları: Türkiye ve Avrupa Birliği Karşılaştırması

Özet

Tarım sektörü, ekonomik üretimin temel bileşenlerinden biri olmasının yanı sıra küresel sera gazı emisyonlarının önemli bir kaynağıdır. Özellikle Paris İklim Anlaşması sonrasında, tarımın çevresel etkileri, karbon ayak izi ve sera gazı azaltım politikaları hem Avrupa Birliği (AB) hem de Türkiye için önemli gündem maddeleri haline gelmiştir. Bu çalışmada, Türkiye ve AB'nin tarım kaynaklı karbon salımları, çevresel baskıları ve izledikleri azaltım politikaları karşılaştırmalı olarak ele alınmıştır.

Karbon ayak izi kavramı; metan (CH_4), azot oksit (N_2O) ve karbondioksit (CO_2) gibi tarımsal faaliyetlerden salınan sera gazlarının çevresel etkilerini ölçmede önemli bir göstergedir. AB ülkeleri, özellikle 2030 karbon azaltım hedeflerine ulaşmak amacıyla Yeşil Mutabakat, Ortak Tarım Politikası (CAP) reformları ve karbon vergilendirme gibi politika araçlarını etkin bir şekilde kullanmaktadır. Türkiye ise Paris Anlaşması'nı geç onaylamış olup tarımsal karbon azaltımı konusunda henüz bütüncül bir strateji oluşturamamıştır. Ancak bazı bölgelerde başarılı pilot projeler ve organik tarımı teşvik eden uygulamalar mevcuttur.

Araştırmada, 75'in üzerinde bilimsel çalışma ve resmi politika belgesi incelenmiştir. Bulgular, AB'nin izleme, raporlama ve karbon ticaret mekanizmaları açısından daha gelişmiş bir yapıya sahip olduğunu ortaya koymaktadır. Türkiye'nin karbon yönetimi süreçlerini geliştirebilmesi için mevzuat uyumu, finansman mekanizmaları ve dijital tarım altyapılarına yatırım yapması önerilmektedir.

Sonuç olarak, tarımın çevresel etkilerini azaltmada hem bölgesel iş birlikleri hem de kurumsal kapasite artırımı önem arz etmektedir. Türkiye'nin, AB ile tarımsal karbon politikaları konusunda daha yakın entegrasyon sağlaması, hem çevresel sürdürülebilirlik hem de ekonomik rekabetçilik açısından stratejik bir zorunluluktur.

ID: 413

Exploring the Impact of the Matrix on the Growth of Listeria monocytogenes

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Abstract

Listeriosis is a significant foodborne illness mainly resulting from the consumption of food contaminated with *Listeria monocytogenes*. The present research aimed to comprehensively examine the growth of foodborne pathogen *Listeria monocytogenes* in readily accessible ultra-high temperature processed bovine milk, infant formula, and two commercial plant-based beverages (almond and coconut) stored at ambient temperature (25°C). Nutrient broth was used as a reference control. Beverage samples were inoculated with *Listeria monocytogenes* at approximately 9×10^7 CFU/mL. The inoculated samples were stored at 25°C and sampled on the 1, 3, 6, 24, 48 and 72 hour of incubation. The findings indicate that *Listeria monocytogenes* was capable of proliferating in all the samples reaching the highest counts on the 48th hour of the evaluation. Although that on the 48th hour of evaluation, coconut beverage had the lowest bacteria counts (7.5±0.98 CFU/mL), no statistically important differences ($P > 0.05$) in growth rates between diverse evaluated beverages was noted. At the 72-hour incubation period, infant formula exhibited the highest microbial counts, at a value of 8 logs, whereas the coconut beverage showed the lowest microbial counts at 6 logs. The obtained data indicate that all the assessed beverages could pose a considerable threat for listeriosis, and post-opening guidelines should be thoroughly evaluated.

Keywords: *Bovine milk, Plant-based beverages, Infant formula, Listeria monocytogenes*

Introduction

Milk is a biologically complex fluid with a distinctive composition that supports the growth and development of newborns. It contains a variety of bioactive compounds known to offer health benefits (Ballard et al., 2013). However, milk also serves as a significant reservoir for foodborne pathogens, including *Listeria monocytogenes* (Erol and Taşçı, 2021; Kahraman et al., 2024; Rugji and Dinçoğlu, 2022; Rugji et al., 2023). *Listeria monocytogenes* is a pathogenic microorganism responsible for foodborne illnesses, and its capacity to endure and potentially exponentiate under a variety of adverse conditions presents a substantial food safety concern (Wang et al., 2024). Although listeriosis remains relatively rare, it can lead to severe, life-threatening infections in vulnerable populations, including infants, pregnant women, the elderly, and individuals with weakened immune systems (Pal et al., 2022).

In recent years, the growing popularity of vegan diets, increasing awareness of lactose intolerance, and heightened environmental consciousness have fueled the demand for plant-based alternatives to cow's milk (Bartula et al., 2023). There has been reported that in Europe, sales increased by 49% from 2018 to 2020, reaching €3.6 billion. According to the Smart Protein report, plant-based milk leads the plant-based product market in 8 of the 11 countries studied (Anon, 2021). While commercially available plant-based beverages are typically heat-treated to ensure microbiological safety, risks persist, such as the potential for cross-contamination post-processing or the survival of spores from spore-forming microorganisms despite ultra-high temperature (UHT) treatment (Bartula et al., 2023). The nutrient-dense composition and high-water activity of these beverages provide an environment conducive to the growth and spread of *L. monocytogenes*, presenting potential food safety hazards.

This study explores how different matrices—plant-based milk alternatives, bovine milk, infant formula, and culture media—affect the growth of *Listeria monocytogenes* when stored at 25 °C.

Materials and Methods

Sources of Samples

The current dataset included four varieties of non-refrigerated UHT samples: whole bovine milk (Migros), almond (Alpro), Coconut (Alpro), Infant formula (Aptamil). Nutrient broth was used as reference control. All the samples were purchased from local store and for consistency, one brand for each beverage was selected for all experiments. Product information is provided in Table 1.

Table 1. UHT beverage composition.

100 g/mL	Bovine milk	Infant formula	Almond beverage	Coconut beverage
Fat	3.1	3.4	1.1	1.2
Carbohydrate	4.7	7.4	3.0	0.0
Protein	3	1.3	0.5	0.1
Salts	0.1	0.0	0.14	0.07

Bacterial Strain and Inoculum Preparation

Listeria monocytogenes ATCC 19115 was used in the current investigation. A loop from each cryogenic (-80°C) stock vial was initially cultured individually in nutrient broth and further maintained on trypticase soy agar (TSA) at 4 °C throughout the study. One isolated colony was transferred to 9 mL of nutrient broth and incubated at 37°C for 24 h. Culture was then sub- cultured onto TSA and incubated at 37°C for 24 h. Following incubation, the microorganism was adjusted to a 0.5 McFarland standard in 9 mL of saline solution. Serial 2-fold dilutions were prepared on saline solution to determine the initial bacterial load.

Experimental Design

Listeria monocytogenes survival was evaluated in five different matrices at 25°C for 72h. The temperature selection for this investigation was based on conditions designed to replicate ambient environments, simulating how inoculated bacteria would behave under post-thermal treatment contamination in the selected beverages. A total of 200 mL sample (Rugji et al., 2023) was inoculated with 1 mL of the prepared strain (9×10^7 CFU/mL). The inoculated samples were stored at 25°C and sampled on the 1, 3, 6, 24, 48 and 72 h of incubation. A total of 100 uL was sampled each time, was serially diluted and plated on TSA. The sampling times and total incubation were adjusted based on experimental feasibility. Experiments were conducted in two biologically independent replicates.

Data Analysis

Results are presented as the mean value ± standard deviation. Statistical analysis was conducted using GraphPad Prism version 10 (GraphPad Software Inc., La Jolla, CA, USA). P values ≤ 0.05 were regarded as statistically significant.

Results and Discussion

The maximum growth rates of *Listeria monocytogenes* at ambient temperature (25°C) were assessed and compared across bovine milk, infant formula, and plant-based, non-dairy beverages. The *Listeria* strain (*Listeria monocytogenes* ATCC 19115) chosen for this study was a standard laboratory strain frequently utilized in food safety research. In a controlled setting, the microorganism demonstrated robust growth in all the tested matrices (Figure 1). However, no statistically significant difference ($P > 0.05$) was found between the various types of beverages. The data from this study showed that *Listeria monocytogenes* was able to grow similarly in a selection of plant-based milk beverages (coconut, almond), infant formula and dairy milk, despite the significant differences in their compositions. An evaluation of bacterial counts 72 hours after incubation showed a numerical decrease; however, the levels remained high enough to pose a food safety risk (Table 2). At the 72-hour time point, the highest bacterial counts were observed in the infant formula, highlighting its significant relevance to food safety and preservation for this product category. While the counts in the plant-based beverages, almond and coconut, were lower at 6.1 and 6, respectively, these levels still represent a public health concern and should be regarded as a potential danger. Furthermore, the positive correlation values observed for the tested beverages indicate a direct relationship between the variables, suggesting that as one factor increases, the other tends to increase as well (Figure 2). The obtained data offer valuable insight into the comparable growth rate of *Listeria monocytogenes*, irrespective of the food matrix. Bartula et al. (2023) investigated the growth of various foodborne pathogens in commercial plant-based beverages and found that *Listeria* strains proliferated more rapidly in plant-based beverages than in bovine milk at both 8°C and 20°C. UHT beverages can be stored at ambient temperature for up to 12 months. Notably, the recommended post-opening storage duration for UHT bovine milk is 3 days under refrigeration, while UHT plant-based beverages can be stored for 5 days at refrigeration temperature. Thus, if these products become contaminated with *Listeria monocytogenes*, this study demonstrates that all can support rapid microbial growth if not stored at appropriate temperatures. Given that *Listeria monocytogenes* can be present on nuts and potentially enter products as a post-processing contaminant, the findings suggest that plant-based beverages may pose a considerable risk for listeriosis. Consequently, post-opening storage guidelines should be carefully reviewed in light of these results. The absence of a significant difference in growth rates between dairy and plant-based products for most of the microbes tested was unexpected, considering the differences in composition. Although plant-based beverages typically contain lower nutrient concentrations than cow's milk, they clearly supply sufficient nutrients to support similar growth rates (Bartula et al., 2023).

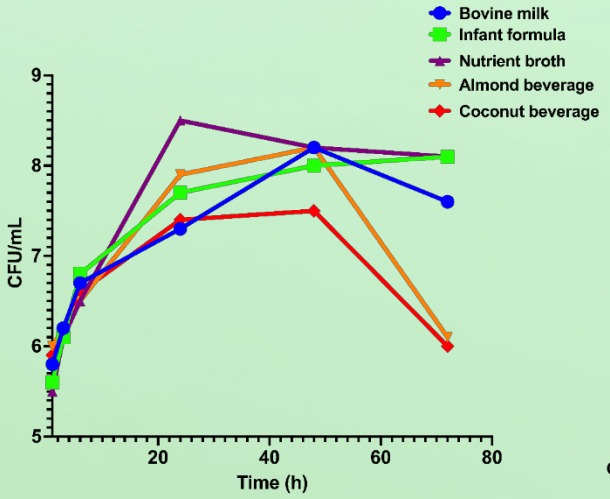


Figure 1. Growth curve of *Listeria monocytogenes* on selected beverages.

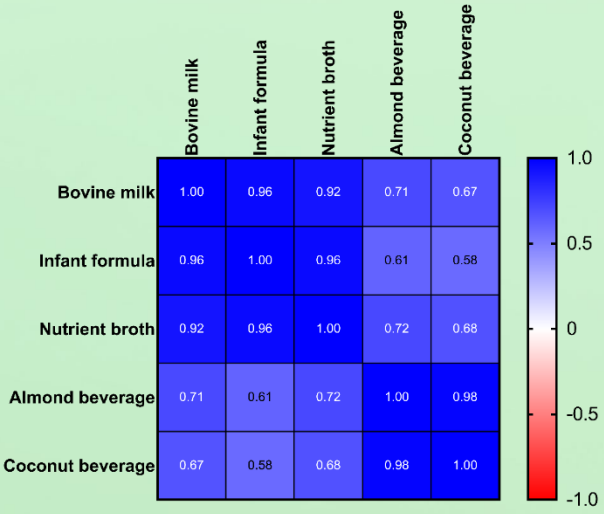


Figure 2. Pearson r correlation results.

Table 2. *Listeria monocytogenes* counts of the artificially contaminated beverages.

Time (h)	1	3	6	24	48	72
Bovine milk	5.8±0.02	6.2±0.00	6.7±0.03	7.3±0.38	8.2±0.11	7.6±0.80
Infant formula	5.6±0.19	6.1±0.17	6.8±0.02	7.7±0.76	8.0±0.49	8.1±0.87
Almond beverage	6.0±0.21	6.2±0.03	6.5±0.31	7.9±0.34	8.2±0.32	6.1±0.12
Coconut beverage	5.9±0.02	6.2±0.01	6.6±0.02	7.4±0.16	7.5±0.98	6.0±0.00
Nutrient broth	5.5±0.21	6.1±0.13	6.5±0.25	8.5±0.81	8.1±0.00	8.1±0.20

This study also emphasizes that the integration of food safety management systems and effective cleaning practices is crucial in the food industry to prevent contamination, ensure product safety, and maintain consumer health (Dinçoğlu and Rugji, 2021).

Conclusion

Overall, the findings presented in this report offer critical insights into the growth dynamics of Listeria monocytogenes, a major foodborne pathogen, across diverse matrices, including the increasingly popular plant-based beverages gaining global traction. These findings must be taken into account when evaluating the risks linked to the production and consumption of plant-based milk alternatives.

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Biosynthesis, production optimization and antifungal property of indole-3-acetic acid from *Pseudomonas aeruginosa* ROO1S

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Abstract

Rhizobacteria colonize the roots of plants after being introduced to seedlings or the rhizosphere through inoculation, thereby stimulating growth. Indole-3-acetic acid (IAA), an essential phytohormone stimulates cell proliferation, growth, and enhance nutrient uptake from the soil. However, IAA has conventionally been produced by chemical synthesis, with practical limitations such as high cost of chemicals which are also not eco-friendly. Sustainability of IAA production from *Rhizobacteria* and their antifungal potential would be an alternative cost effective and natural approach to overall plant health. Isolation and screening for indole-3-acetic acid producing bacteria from plant rhizosphere was done using a chemically-defined medium and Salowisky reagent. Quantification of IAA produced by selected isolates, through submerged fermentation was estimated with a Spectrophotometer. Molecular identification of highest producer was done using standard methods while production parameters were optimized for improved IAA yield. Antifungal activity against selected pathogen was analysed with the dual culture method. Change in color to pink after addition of Salowisky reagents indicated the presence of indole-3-acetic acid. The concentrations of IAA produced from selected isolates ranged between 218.88 ± 0.00 and 393.88 ± 0.01 µg/mL. Highest IAA-producing bacteria was identified as *Pseudomonas aeruginosa* ROO1S (Accession PV123886). Optimal IAA production was obtained at 25°C (463.88 µg/mL), with 2g/L tryptophan substrate (505.13 µg/mL), tryptone (613.87 µg/mL) and mannitol (718.87 µg/mL) as nitrogen and carbon sources respectively, and 150 rpm agitation (356.38 µg/mL). Optimisation yielded 865.13 µg/mL of IAA. The extracted compound exhibited antifungal activity. Conclusively, *Pseudomonas aeruginosa* ROO1S is an IAA-producing bacteria. Optimisation increased IAA production and the compound exhibited inhibitory properties against fungal phytopathogen.

Key Words: *Rhizobacteria, phytohormones, Indole-3-acetic, Salowisky reagent, P. aeruginosa*

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Prevention of Fish Oil Oxidation by Melaleuca quinquenervia Essential Oil: Dose Dependent Antioxidant Effects

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Abstract

Fish oil, rich in omega-3 polyunsaturated fatty acids (PUFAs), is widely recognised for its health benefits. However, its susceptibility to oxidation poses a significant challenge and leads to reduced nutritional quality and potential health risks. This study investigates the antioxidant activity of Melaleuca quinquenervia essential oil (MQEO) in fish oil and compares it with the synthetic antioxidant butylated hydroxytoluene (BHT). Experimental groups were formed by adding different concentrations of MQEO (100-800 ppm) to fish oil and oxidation levels were evaluated by peroxide value (PV) and malondialdehyde (MDA) measurements. The results showed that higher concentrations (≥400 ppm) of MQEO showed significant antioxidant activity by effectively reducing peroxide formation and lipid peroxidation compared to BHT. The major active components of MQEO, such as eucalyptol, viridifluorol and α-terpineol, contributed to its protective effect by inhibiting lipid oxidation. Given the growing concerns about the safety of synthetic antioxidants, MQEO offers a promising natural alternative to protect lipid-based products susceptible to oxidation. The findings suggest that MQEO may improve fish oil stability and extend shelf life while reducing potential health risks associated with synthetic preservatives.

Key Words: *Fish oil, Melaleuca quinquenervia, oxidation, antioxidant, lipid peroxidation*

Introduction

Fish oil, rich in omega-3 polyunsaturated fatty acids (PUFAs) such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), is a widely recognized dietary supplement due to its anti-inflammatory, neuroprotective, and cardioprotective properties. EPA and DHA contribute to cardiovascular health by regulating lipid metabolism and improving endothelial function (Harris, 2004). DHA is crucial in neuronal membrane integrity and cognitive function (Das et al., 2009). Additionally, omega-3 fatty acids' anti-inflammatory effects suggest their potential in managing metabolic and autoimmune diseases.

As the human body cannot synthesize omega-3 fatty acids endogenously, dietary intake or supplementation is necessary. Fish oil, derived from species like anchovies, sardines, mackerel, and tuna, has gained global popularity, particularly among individuals prioritizing preventive healthcare (Pike & Jackson, 2010; Tocher, 2010). However, the rising demand for fish oil raises concerns regarding marine resource sustainability. Overfishing, habitat degradation, and climate change threaten fish stocks, with reports indicating severe depletion of global fish populations (Barange et al., 2018; FAO, 2022). Given these challenges, alternative omega-3 sources are essential to mitigate environmental risks while maintaining health benefits (Jackson, 2006).

Fish oil easily oxidizes because of its high content of unsaturated fatty acids (PUFAs) (Kazuo, 2019). PUFAs attract free radicals and oxygen by the typical mechanism of its multiple double bonds reacting, leading to the oxidative degradation of PUFAs. As they get oxidized, secondary oxidation products involving hydroperoxides, aldehydes, and ketones are produced, and such substances are catalyzed by fish meal. Besides, they may be potential health hazards to the consumer (Min & Boff, 2002). Both taste and odor disorders are caused by fish oil oxidation and decreased nutritional value. In addition, oxidized lipids cause cellular damage by oxidative stress and threaten human health (Shahidi & Zhong, 2010). For this reason, it is a must to add antioxidant compounds to fish oil products to avoid oxidation.

Nowadays, most fish oils take advantage of synthetic antioxidants in the production process. Butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) are frequently chosen as antioxidants for the food industry to prevent fat oxidation. However, new research has found that synthetic antioxidants may have potentially toxic effects and long-term health risks (Arneson & Roberts, 2007). The result is growing interest in natural sources of these compounds. Among these, the rule to contain oxidizes know-how to do so and are known as natural and, therefore, safe alternatives in food products (Ambrosio et al., 2021) are those derived from plants.

The study aimed to assess the antioxidant activity of Melaleuca quinquenervia essential oil in fish oil and to compare it with BH, a synthetic antioxidant. Experimental groups were formed by adding various proportions of Melaleuca quinquenervia essential oil to fish oil samples, and antioxidant activity was evaluated by intermittent measurement of the peroxide values. The study is predicted to bring significant outputs to the industry of natural antioxidants in the food sector.

Materials and Methods

Oxidation Experiments

The fish oil for which this research was obtained is from a Turkish company, a company that is professionally engaged in the production of fish oil for human consumption. Additionally, various concentrations of MQEO (100ppm, 200ppm, 400ppm, 800ppm) were dissolved in fish oil; having formed distinct experimental groups that were established to analyze its protective effect against the thermal oxidation of fish oil. Moreover, Butylated hydroxytoluene (BHT200) was used as a positive control at a concentration of 200 ppm. The treatments of the experimental afore-mentioned groups were implemented over a period of 96 hours, keeping them at a twofold climate of 55±0.5 °C that can be sustained by temperature-resistant containers and 70% humidity. Light was turned on to maintain the 7000 luxs level as cited in the paper (Kesbiç et al., 2023).

Peroxide Value

The peroxide value determination method (Cd 8b-90) established by the American Oil Chemists' Society (AOCS) was used to assess the protective efficacy of MQEO against oxidation under accelerated conditions. Unoxidized fish oil and 0.5 g samples from the oxidized experimental groups were dissolved in 5 mL of chloroform. The dissolved samples were then incubated with 15 mL of acetic acid and 1 mL of saturated potassium iodide for 10 minutes at ambient temperature and in the absence of light. Following incubation, titration was performed using 0.01 N sodium thiosulfate and a few drops of 1% starch in 75 mL of deionized water as the indicator. The peroxide value was calculated using a formula based on the color change that indicated the result of the titration.

$$PV\ (\%) = [(V1 - V0)\ N] / V$$

V1 and V0 denote the titrant volumes employed for the sample and blank, respectively; N represents the normality of the titration solution, and M indicates the sample weight. The peroxide value assay findings were assessed in triplicate as meq O_2 kg^{-1} oil.

Measurement of the MDA levels

The quantity of malondialdehyde (MDA) generated during lipid peroxidation has been determined using the method developed by Ohkawa et al. (1979), which relies on the reaction between thiobarbituric acid (TBA) and MDA. The intensity of the colorful reaction complex generated by MDA and TBA was quantified spectrophotometrically at a wavelength of 532 nm. Results are expressed as nmol MDA/mL (Ohkawa et al., 1979).

Volatile Components of Neroli Oil by GC-MS

Different MQEO volatile components based on GC-MS analysis were achieved using RTX-5MS capillary column. The process was carried out at 40°C oven temperature, and the injection volume was 1µL. This was compared to peaks in the W9N11 library. Thus, the volatile component profile of the oil was ascertained.

Statistical Analysis

Data are expressed as the mean ± standard deviation (SD). Statistical analyses were conducted using IBM SPSS Statistics version 20. A one-way ANOVA test was performed to assess the significance of differences among the sample groups, followed by group comparisons using Tukey's HSD (Honest Significant Difference) test. A significance threshold of $p < 0.05$ was applied in all analyses.

Results and Discussion

The peroxide values of the experimental groups after rapid oxidation showed significant variation ($P < 0.001$), indicating differing levels of oxidative stability among the treatments (Table 1). The oxidized fish oil group exhibited the highest peroxide value (75.18±0.99 meq O_2 kg^{-1}), confirming extensive lipid oxidation. In contrast, the fresh fish oil group had the lowest peroxide value (4.59±1.19 meq O_2 kg^{-1}), reflecting its unoxidized state. The synthetic antioxidant BHT (200 ppm) significantly reduced peroxide formation (26.48±0.75 meq O_2 kg^{-1}), showing a strong protective effect. Among the Melaleuca quinquenervia essential oil (MQEO) treatments, MQEO8 demonstrated the greatest antioxidant activity, resulting in the lowest peroxide value (21.12±0.87 meq O_2 kg^{-1}), followed by MQEO4 (24.24±0.72 meq O_2 kg^{-1}) and MQEO2 (24.62±0.65 meq O_2 kg^{-1}), which were statistically

similar to BHT. MQEO1 exhibited a slightly higher peroxide value (32.84±1.35 meq O_2 kg^{-1}), but still significantly lower than oxidized fish oil. These findings suggest that MQEO, particularly at higher concentrations, effectively mitigates oxidative degradation in fish oil, comparable to the synthetic antioxidant BHT.

Table 1. Peroxide amounts of experimental groups after rapid oxidation.

Experimental Groups	meq O_2 kg^{-1}	P value
Oxidized Fish Oil	75.18±0.99[a]	< 0.001
BHT 200	26.48±0.75[c]	
MQEO1	32.84±1.35[b]	
MQEO2	24.62±0.65[c]	
MQEO4	24.24±0.72[c]	
MQEO8	21.12±0.87[d]	
Fresh Fish Oil	4.59±1.19[e]	

Melaleuca quinquenervia essential oil (MQEO)

As a result of MDA analysis in the samples, it was determined that the levels in oxidised oil and MQEO4, MQEO8 and BHT 200 groups were significantly higher than fresh fish oil group ($P<0.05$). While the MDA level in MQEO1 group was significantly lower than the oxidised oil group ($P<0.05$), there was no significant difference between MQEO2 group and fresh fish oil group ($P>0.05$). The levels of the experimental groups are presented in Figure 1.

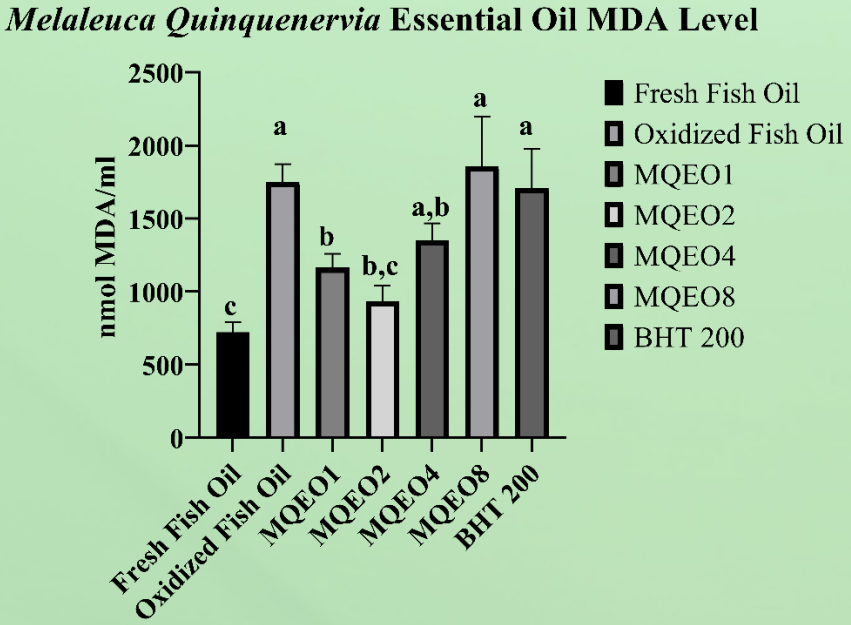


Figure 1. The MDA levels of the Experimental Groups.
Different letters indicate statistical differences between groups.

As a result of the analysis of the volatile components of *Melaleuca quinquenervia* essential oil, eucalyptol with a content of approximately 56%, viridifluorol and alpha terpineol with a ratio of 10% were determined. 1,8-Cineole (eucalyptol) is the main ingredient of *Melaleuca quinquenervia* essential oil and is, therefore, a monoterpene with beneficial antioxidant and antimicrobial properties. It has been evidenced that 1,8-Cineole, as an antioxidant, inhibits the peroxidation of lipids and is a source to neutralize the oxidative stress caused by the free radicals (Slamenova & Horvathova, 2013). Still, not only does it protect the cellular tubulin, but, also, 1,8-cineole acts in the DNA molecule thus attributing to the stability of the DNA and reduces the power of the inflammatory process (Mohammed et al., 2023). This element is also used in food preservation processes as a natural antioxidant which eliminates the necessity of the incorporation of synthetic antioxidants (Chrysargyris et al., 2020).
Virdifluorol, however, is a bioactive sesquiterpene with a mechanism to inhibit lipid oxidation by neutralizing free radicals. Studies have revealed that the essential oils containing viridiflorol represented remarkable DPPH radical scavenging activity and this compound presented a high antioxidant capacity which is known to be critical in shielding against oxidative stress (Mohammed et al., 2023). In addition, Viridifluorol has also been reported to stabilise biological systems by protecting cell membranes against oxidative stress (Macêdo et al., 2022). The use of essential oils containing viridifluorol is growing in the food industry, especially in fat-containing food products with long shelf life (Cutillas et al., 2017).

Another important component α-Terpineol is known for its strong antioxidant and anti-inflammatory properties. It has been shown that α-Terpineol reduces oxidative stress levels by reducing reactive oxygen species (ROS) and exhibits cell protective effects (Rodríguez et al., 2013). However, studies have shown that α-Terpineol inhibits lipid peroxidation and slows down oxidative deterioration in fat-based foods (Singh et al., 2009). Furthermore, α-Terpineol has been reported to reduce oxidative stress-induced inflammation by acting on anti-inflammatory mechanisms (Farhat & Jordán, 2009). Due to these properties, α-Terpineol is an important component that can be used as a natural antioxidant in the food industry.

Melaleuca quinquenervia essential oil exhibits a strong antioxidant activity thanks to the synergistic effect of these three components and provides a potential contribution to extend the shelf life of food products by preventing oxidative deterioration. As an alternative to synthetic antioxidants, the advantages of using these compounds obtained from natural sources, especially in oxidation-sensitive lipid-based foods such as fish oil, are becoming increasingly important.

In conclusion, the use of *Melaleuca quinquenervia* essential oil 200 ppm and above provided as effective protection as the commercially used synthetic antioxidant and the maximum application dose to suppress the oxidation process of fish oil accelerated by temperature, humidity and light.

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Practices to Reduce Offspring Mortality in Sheep and Goat Husbandry

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Abstract

The economic success of farms with small ruminants depends to a large extent on increasing the number of offspring weaned per animal and reducing production costs. On small ruminant farms, all types of investments made throughout the year are not as effective as those made during the birthing period. Increasing the productivity level of the animals while reducing the associated losses of offspring are the key words for profitable and sustainable farming with small ruminants. It is well known that the most important factor affecting productivity in sheep and goat farming is the yield of offspring, and lamb and goat incomes depend on the level of fertility, the proportion of lambs and kids reared and the live weight of lambs and kids. Litter mortality varies depending on the production system and type of husbandry on the farm. These deaths usually occur in the first ten days after birth. Some precautions to be taken during these processes contribute significantly to the survival of the offspring. Worldwide, litter mortality in small ruminants varies between 4-21% depending on heredity and environmental factors. Most deaths in the offspring occur in the first week after birth. Some of these deaths are due to litter shedding, while others are due to postnatal bacterial or viral infections. A high number of lambs and kids at birth only makes sense if the losses of lambs and kids until weaning or marketing are low. For this reason, measuring reproductive performance as a function of growth results gains economic significance. In this context, this study aimed to investigate practices to reduce progeny mortality in small ruminant breeding.

Key Words: *Sheep, Goat, Lamb, Kids, Offspring Mortality*

Koyun ve Keçi Yetiştiriciliğinde Yavru Ölümlerinin Azaltılmasına Yönelik Uygulamalar

Özet

Küçükbaş hayvancılık işletmelerinin ekonomik başarısı, büyük ölçüde hayvan başına sütten kesimdeki yavru sayısının arttırılması ve üretim giderlerinin azaltılmasına bağlıdır. Küçükbaş hayvancılık işletmelerinde yıl boyunca yapılan her türlü yatırım, doğum dönemindeki yatırımlar kadar etkili değildir. Hayvanlarda verim düzeyini artırırken buna bağlı yavru kayıplarını azaltmak, karlı ve sürdürülebilir küçükbaş hayvancılık için anahtar kelimelerdir. Koyun ve keçi yetiştiriciliğinde verimliliği etkileyen en önemli etmenin yavru verimi olduğu bilinmektedir ve kuzu ve oğlak gelirleri döl verim düzeyi ile birlikte büyütülen kuzu ve oğlakların oranı ile kuzu ve oğlakların canlı ağırlıklarına bağlıdır. Yavru ölümleri, işletmelerde uygulanan üretim sistemi ve barındırma yönetimine bağlı olarak değişiklik göstermektedir. Bu ölümler, daha çok doğumu izleyen ilk on gün içinde gerçekleşmektedir. Bu süreçlerde alınacak bazı önlemler yavruların yaşama gücüne önemli katkı sağlamaktadır. Dünya genelinde küçükbaş hayvanlarda yavru ölümleri, kalıtsal ve çevresel faktörlere bağlı olarak %4-21 arasında değişmektedir. Yavru ölümlerinin çoğu doğumu izleyen ilk hafta içinde gerçekleşmektedir. Bu ölümlerin bir kısmı yavru atmadan, diğer önemli bir kısmı ise doğum sonrası bakteri ya da viral enfeksiyonlardan kaynaklanmaktadır. Doğumda kuzu ve oğlak sayısının yüksekliği ancak sütten kesim veya pazarlama dönemine kadar kuzu ve oğlak kayıplarının azlığı ile anlam kazanır. Bu nedenle büyütme sonuçlarına göre döl verim ölçütleri ekonomik olarak geçerlilik kazanır. Bu bağlamda bu çalışmada küçükbaş hayvan yetiştiriciliğinde yavru ölümlerinin azaltılmasına yönelik uygulamaların incelenmesi amaçlanmıştır.

Anahtar Kelimeler: *Koyun, Keçi, Kuzu, Oğlak, Yavru Ölümleri*

Giriş

Küçükbaş hayvanlar, özellikle yerli ırklar, sosyo-ekonomik açıdan tropik bölgelerdeki insan nüfusunun büyük bir bölümünün geçim kaynaklarında önemli bir rol oynamaktadır (Ahsani ve ark., 2010; Muhammedabadi, 2021; Masoudzadeh ve ark., 2020). Koyun ve keçi üretim işletmelerinin ekonomik ve biyolojik etkinliği genel olarak koyunların ve keçilerin verimliliğini ve üreme performansını artırarak iyileşmektedir (Zamani ve ark., 2015; Muhammedabadi, 2016; Amiri Roudbar ve ark., 2017, Amiri Roudbar ve ark., 2018; Ghotbaldini ve ark., 2019).

Genç kuzuların ve oğlakların ölüm oranları, özellikle geniş otlatma sistemlerine sahip bölgelerde oldukça yüksek olabilir. Küresel olarak, kuzular için sütten kesme öncesi ölüm oranı ortalama %15-20'dir (Flinn ve ark., 2020). Ancak Afrika, Hindistan ve Avustralya'nın tropikal meralarında bu oranlar keçiler için %30'u aşabilmektedir (Chen ve ark. 2024). Afrika'da kuzu ölümleri farklı koyun popülasyonları arasında %9 ila %76 arasında değişmektedir ve yaş, ırk ve üretim sisteminden etkilenmektedir. Kuzu ve oğlak ölümlerini azaltarak düşük girdili çiftçilik sistemlerinde küçükbaş hayvan üretim verimliliğini artırmaya acil bir ihtiyaç vardır (Mthi ve ark. 2020). Araştırmalar, genetik, çevresel ve yönetim faktörlerinin yüksek kuzu ve oğlak ölüm oranlarında etkili olduğunu göstermektedir. Bu faktörler arasında düşük doğum ağırlığı, cinsiyet, kuzulama veya oğlaklama sırasında yaş ve vücut ağırlığı, yetersiz kolostrum, yavrulama mevsimi ve yılı ile yavru verimi yer alır (Ibrahim ve ark. 2020; Flinn ve ark. 2020; Bangar ve ark. 2022; Ceyhan ve Kozaklı, 2023; Chen ve ark. 2024).

Anwar ve ark. (2024) yaptıkları çalışmada, kuzu ve oğlaklarda morbidite ve mortalite oranlarını azaltmak için anne bakımının iyileştirilmesi, kolostruma erişim, daha iyi bağ kurma ve çoklu doğumlar için uygun ortamların sağlanması gerekliliğini vurgulamaktadır. Habtegiorgis ve ark. (2022) koyun başına kuzular arasında ölüm oranını azaltarak pazarlama döneminde yavru büyüklüğünü ve ağırlığını artırmak, toplum temelli ıslah programının hedefi olduğunu belirtmiştir. Yaptıkları çalışmada, dişilerin hayatta kalma şansı erkeklere göre daha düşük ve üçüzler, dördüzler ve düşük doğum ağırlıklı (≤2 kg) doğan kuzular için hayatta kalma şansının düşük olduğunu bildirmiştir. Ek olarak üreme ve büyüme performansını iyileştirmeyi amaçlayan devam eden seleksiyon programı, kuzuların hayatta kalma oranı üzerinde olumlu bir etkiye sahip olduğu bildirilmiştir. Sürüdeki ortamın iyileştirilmesi, çoklu doğumlar için özel bakım ve küçük kuzular için bakım, kuzu sağkalımının daha da iyileştirilmesine yol açacağı bildirilmiştir.

Küçükbaş hayvan yetiştiriciliğinde yenidoğan ölümleri son yıllarda önemini korumakla beraber, önemli bir çiftlik geliri kaybını temsil etmekte, israfa katkıda bulunmakta ve hayvan refahını da olumsuz etkilemektedir (Dwyer ve ark., 2016). Biyolojik olarak, doğumdan sonra mümkün olan en kısa sürede iyi bir kolostrum alımının sağlanmasının yenidoğan sağkalımı için çok önemli olduğu açıktır. Bu, termoregülasyon, pasif immünolojik koruma için destek sağlar ve koyun ile kuzu arasındaki bağlantının geliştirilmesinde rol oynar. Kuzunun doğumdan sonra memeyi bulma ve hızlı bir şekilde emme davranışı, yeterli kolostrumun yutulmasını sağlamada önemli bir bileşendir. Deneysel çalışmalarda, kuzu ölümleri için ana risk faktörleri, özellikle gebelik sırasında yetersiz anne beslenmesi, doğum zorluğu, altlık materyali ve genetik nedeniyle düşük doğum ağırlığıdır ve bunların tümü kısmen kuzunun memeye ulaşma ve emme hızı üzerindeki etkilerine bağlanabilir. Benzer şekilde, ticari çiftliklerde, düşük doğum ağırlığı ve emme ile ilgili sorunlar, ölüm oranına önemli katkıda bulunan nedenler olarak tanımlanmıştır. Epidemiyolojik çalışmalarda, zor doğumlarda yardım sağlama gibi yönetim faktörlerinin, barınma ile ilişkili risk faktörlerinden daha önemli olduğu bildirilmiştir. Sosyal bilim çalışmaları, çiftçilerin genellikle yenidoğan ölümlerini iyileştirme konusunda olumlu bir tutuma sahip olduklarını, ancak bunun nasıl başarılabileceğine dair inançlarda farklılık gösterebileceğini, bazı çiftçilerin erken kuzu ölümleri üzerinde hiçbir kontrole sahip olmadıklarına inandıklarını göstermektedir. Çiftçilerin ve danışmanların yenidoğan sağkalım stratejileri geliştirmek için birlikte çalıştıkları kolaylaştırıcı yaklaşımların, kuzu ölümlerinde azalmaya yol açan koyun beslenmesini optimize etmek gibi yönetim hedeflerine ulaşmada etkili olduğu görülmektedir. Sonuç olarak, bilimsel araştırmaların, optimal doğum ağırlıkları, kuzu canlılığı ve yeterli kolostrum alımının önemini anlama gibi yenidoğan sağkalımını destekleyen biyoloji hakkında yararlı bilgiler sağladığı belirtilmiştir, ancak bu bilginin aktarılması, çiftlikte yönetim değişikliği psikolojisinin daha iyi anlaşılmasından fayda sağlayacaktır. Ek olarak, yeterli çiftlik kayıtlarına dayanarak, yenidoğan ölümleri ile ilgili şu anda önemli olan bilimsel literatürden yararlanan özel çözümler geliştirmek, yenidoğan ölümlerinin azaltılmasına yardımcı olacaktır (Dwyer ve ark., 2016). Kuzu ve oğlak ölümlerini azaltmak için önleme programlarının geliştirilmesi, ölüm modellerinin bireysel çiftlik bazında değerlendirilmesiyle başlar. Kuzunun rahim içinde mi yoksa rahim dışında mı öldüğünü ve süt alıp almadığını belirlemek, mevcut sorunları ve olası çözümleri tanımlamak için kritik öneme sahiptir. Önleme programları, en yüksek etki potansiyeline sahip alanlardaki kayıpları hedeflemek için önceliklendirilmelidir. Yüksek etki alanlarına örnek olarak anne beslenme programlarının optimize edilmesi, doğum ortamının iyileştirilmesi (ısı ve nem), melezleme programlarının kullanılması ve aşılar gibi hastalık önleme programlarının uygulanması öncelikli konulardır (Young ve ark., 2014).

Yavru ölümleri, işletmelerde uygulanan üretim sistemi ve barındırma yönetimine bağlı olarak değişiklik göstermektedir. Bu ölümler, daha çok doğumu izleyen ilk on gün içinde gerçekleşmektedir. Bu süreçlerde alınacak bazı önlemler yavruların yaşama gücüne önemli katkı sağlamaktadır. Dünya genelinde küçükbaş hayvanlarda yavru ölümleri, kalıtsal ve çevresel faktörlere bağlı olarak %4-21 arasında değişmektedir. Yavru ölümlerinin çoğu doğumu izleyen ilk hafta içinde gerçekleşmektedir. Bu ölümlerin bir kısmı yavru atmadan, diğer önemli bir kısmı ise doğum sonrası bakteri ya da viral enfeksiyonlardan kaynaklanmaktadır (Taşkın ve ark., 2005; Taşkın, 2014). Ülkemizde kuzu ve oğlak ölüm oranları yetiştirilen hayvanların genotip/ırk ve üretim sistemine bağlı olarak %9.5-14.43 arasında değişmektedir. Prenatal (doğum öncesi), neonatal (doğum sonrası ilk hafta) ve erken postnatal(yedinci gün ile sütten kesim arası dönem) ölümlerinin yüksek olmasının nedenleri arasında; doğuma bağlı anormallikler enfeksiyon ve hastalıkların yanı sıra düşük vücut ısısı, yeterli beslenememe ve düşük canlı ağırlık sayılmaktadır. Küçükbaş hayvancılık işletmelerinde karlılık ve sürdürülebilirlik, yeni doğan yavruların hayatta kalabilme gücü ile yakından ilişkilidir. Neonatal dönem, kuzu ve oğlaklarda hastalıkların ve ölümlerin meydana geldiği en kritik evrelerden biridir. Neonatal kayıplar genellikle düşük/yüksek doğum ağırlığı, distosi (zor doğum), düşük/yüksek kondisyon skorları, zayıf annelik davranışı, yetersiz kolostrum alımı, enfeksiyöz hastalıklar ve çevresel koşullar ile yakından ilişkilidir (Ünal ve ark., 2018; Tölü ve ark., 2007) Doğumlar sırasında olası yavru ölümlerini azaltılmasına yönelik öncelikli konular arasında işletmede uygun bir sürü yönetimi uygulanması ve hayvan refahının sağlanması yer almaktadır. Ülkemizde küçükbaş hayvan yetiştiriciliği yapan aile tipi işletmelerde genellikle ağıl temel birimleri tek bir çatı altında (bütünleşik ağıl yapı sistemi) düzenlenmiş olup, bu birimler yapı tekniği, hijyen, havalandırma yönünden yetersiz, diğer ağıl birimlerinin pek çoğu ise yok ya da yeterli değildir. Ayrıca bu tip ağıl yapılarında özellikle iklimsel faktörlerin olumsuz etkilerine karşı gerekli koruma sağlanamadığı için yavru ölümleri önemli bir sorun oluşturmaktadır (Ünal ve ark., 2018; Ceyhan ve ark., 2015).

Koyun ve Keçi Yetiştiriciliğinde Ölüm Oranlarını Etkileyen Faktörler

Kuzu - Oğlakların Barındırması ve Kolostrum (Ağız Sütü)

Yeni doğan yavrular için ilk 48 saat çok önemli olup bu süre altın saat olarak kabul edilir. Ağıllardaki doğum bölmeleri ve kolostrum uygulaması (ilk 6-12 saat içinde) yavru ölümlerinin önlenmesi bakımından oldukça önemlidir. Yeni doğan yavrularda açlık ve soğuk şokunda kaynaklanan ölümlerin önlenebilmesi için yavruların mutlaka doğumu izleyen ilk 6-12 saat içinde yeterli kolostrum almaları sağlanmalıdır (Goddard ve ark., 2006). Yeni doğan yavrularda açlık ve soğuk şoku, doğum sonrası yavru ölümlerinin önemli nedenleri arasında yer alır. Bu yavruları emiştirme/büyütme dönemi sonuna kadar sağlıklı ve canlı tutmayı başarmak, yavruların doğumu izleyen ilk 6-12 saat içinde yeterli ağız sütü (kolostrum) almaları ile olasıdır. Yavrular çevre koşullarına karşı korumasız ağıl ya da merada doğduklarında, ilk 18 saat içinde her 500 g vücut ağırlığı için yaklaşık 95 g kolostruma gereksinim duyarlar. Buna karşın kapalı ortamda 5-10 °C' de doğduklarında ilk 18 saat içinde her 500 g vücut ağırlığı için yaklaşık 80 g kolostruma gereksinim duyarlar (Gökçe ve ark., 2013; Ünal ve ark., 2018) Kuzu ve oğlakların barındırıldığı alanlarda özel olarak tasarlanmış besleme, ısıtma ve havalandırma sistemleri gerekmektedir. Yavruların barındırıldığı yapılarda, özellikle hijyenin sağlanması ve hastalıkların kontrol altına alınabilmesi için yeterli taze hava girişini sağlayacak etkin bir havalandırmaya gereksinim duyulmaktadır. Havanın temiz, nemden ari ve uygun bir hava akımının olması sağlanmalıdır. Bununla birlikte bölme içine rüzgârla hava girişi mutlaka önlenmelidir. Yavru bölmelerinin kuru ve drenajının çok iyi olması, hayvan hareketleri için yeterli büyüklükte ve yaralanmalara neden olmayacak şekilde tasarlanmasına dikkat edilmelidir (Ünal ve ark., 2018).

Ağıl Yapı Sistemi ve Üretim Sisitemleri

Barındırmada, çevre istekleri ve üretim sistemleriyle birlikte hayvan refahının dikkate alınması gerekmektedir. Koyun ve keçi barındırma biçimi, işletmenin amacının (sütçü, etçi, kombine ya da damızlıkçı) yanı sıra doğum mevsimi ve iklim gibi etmenlere bağlı olarak ülkeden ülkeye ve hatta bölgeden bölgeye değişiklik gösterebilmektedir.

Küçükbaş hayvan yetiştiriciliğinde üretim sistemleri, bölgelere ve hatta illere göre farklılık gösterebilmektedir. Bu nedenle, doğru üretim sisteminin seçimi, üremenin başarılı bir şekilde kontrol edilmesi ve yavru ölüm oranlarının sınırlandırılmasında karlılık ya da sürdürülebilirlik açısından oldukça önemlidir

Gebelik Döneminde Aşılama

Gebeliğin son döneminde yapılan aşılamalar, kolostral antikor düzeylerini artırarak neonatal kayıpları azaltır. Koyun ve keçilerde neonatal kayıpların önlenmesi rotoksemi, kuzu dizanterisi ve tetanoza bağlı kuzu ve oğlak kayıplarının önlenmesi için gebe koyunlarda klostridial aşılama programları önem arz eder.

Kuzu ve Oğlak Ölümlerinin Spesifik Nedenleri

Neonatal kuzu ve oğlaklarda, non-enfeksiyöz ve enfeksiyöz hastalıklar mortalitenin en önemli sebepleridir.

Çizelge 1. Küçükbaş hayvancılık işletmelerinde üretim sistemleri ve özellikleri (Taşkın ve ark., 2015)

Üretim sistemi	Üstünlükler	Sakıncalar
İlkbahar yavrulaması	• Yavru ölüm oranı düşük • Yem giderleri düşük • Barınma giderleri az • Kaba yem gereksinimini meradan karşılama	• İşgücü gereksinimi fazla • İç ve dış parazit mücadelesi fazla • Pazarlama ağırlığı düşük
Kış yavrulaması	• Parazitler daha az • Pazar potansiyeli yüksek • Yavru gelişimi daha iyi • İşgücü gereksinimi az	• Yavru ölüm oranı yüksek • Yem giderleri yüksek • Sağlık sorunları fazla • Barındırma giderleri yüksek
Yılda birden fazla yavrulama	• Yavru ölüm oranı düşük • Yıl boyu yavru pazarlayabilme • Hayvan başına fazla yavru satışı	• İşgücü gereksinimi fazla • Yem giderleri yüksek • Meme-ayak sorunları fazla • Doğum bölmesi gerektirir

Çizelge 2. Küçükbaş hayvancılık işletmelerinde ağıl sistemlerinin genel yapısal özellikleri (Ünal ve ark., 2006; Olgun, 2011)

Yapısal Özellik	Açıklama			
	İklimlendirmeye göre	Yapı tipine göre	Yapı şekline göre	Zemin düzenlemesine göre
Konstrüksiyon	• Soğuk ağıl (Doğal havalandırmalı) • Sıcak ağıl (Mekanik havalandırmalı ve ısıtmalı)	• Açık(sundurma) ağıl • Yarı açık ağıl • Kapalı ağıl • Tünel ağıl	• I tipi • U tipi • T tipi • L tipi	• Toprak zeminli • Beton zeminli • Izgara zeminli
Temel Birimler	• Damızlık koyun/keçi birimi • Bireysel/grup bölmeli doğum birimi • Yavru büyütme birimi • Sütten kesilmiş kuzu/oğlak birimi • Damızlık genç hayvan (erkek toklu/çepiç) yetiştirime birimi • Genç (dişi toklu/çepiç) ve damızlık erkek hayvan (teke/koç) birimi • Sağım yeri • Revir • Karantina bölmesi			
Diğer Birimler (Servis yapı ve tesisler)	• Hayvan yönetim tesisleri (Toplama ve sıkıştırma bölümleri, tartım ünitesi, ayak ve derin banyoluklar, kırkım yeri, yükleme rampası) • Yem ve gübre depolama yapıları (Silaj, kaba ve yoğun yem depoları, gübre çukuru) • Bakıcı konutu/idare binası • Hangar/garaj • Rüzgar kıranlar			

Non-enfeksiyöz Nedenler

Kuzu ve oğlaklarda non-enfeksiyöz hastalıklar genellikle sürü yönetimindeki hatalar ile ilişkili olup, doğumdan sonraki ilk bir hafta içinde ölümlerin en önemli sebebidir. Kuzu ve oğlak ölümlerinin en önemli nedenleri; güç doğum, erken doğum, hipotermi/hipoglisemi kompleksi (annenin yavruyu kabul etmemesi, yetersiz beslenme, açlık, soğuk hava, düşük doğum ağırlığı), vitamin iz element eksiklikleri, travma ve konjenital anomalilerdir.

Enfeksiyöz Hastalıklar

Neonatal dönem kuzu ve oğlak ölümlerinin %12'si enfeksiyöz hastalıklarla ilişkilidir. Neonatal dönem enfeksiyöz hastalıkların ortaya çıkmasında, kalabalık ağıllarda kuzuların anneleri ile bir arada bulundurulmaları, çok sayıda kuzunun bir arada bulundurulması, hastaların sağlıklılardan ayrılmaması, etkin tedavilerin yapılmaması, gebelik dönemi ve yeni doğanlarda aşı programlarının oluşturulmaması, kötü kolostrum yönetimi sonucu yeterli bağışıklığın gelişmemesi en önemli risk faktörleridir. Neonatal dönemde enfeksiyöz hastalıkların erken teşhisi, tedavinin hemen başlatılarak hastalığın yayılmasının önlenmesine yardımcı olur. Koyun ve keçiler, diğer çiftlik hayvanlarına göre tedaviye daha sınırlı cevap verir. Bu nedenle, enfeksiyöz hastalıkların tedavisinden ziyade önlenmesi önemlidir.

Sonuç ve Öneriler

Koyun/keçi işletmelerinde yavruların canlılığı, sağlığının korunması ve geliştirilmesi, doğum öncesi dönemin iyi yönetimi, sürü bazında doğru stratejilerin oluşturulması ve bireysel hayvan bazında doğru uygulamaları içeren

uygulamalar ile sağlanabilir. Koç seçimi, annelerin aşılanması, gebelik döneminde yavru sayısının belirlenmesi ve gebelik dönemindeki beslenme gibi faktörler yavruların canlılığı ve sağlığını önemli ölçüde etkilemektedir. Bireysel ya da grup düzeyinde doğum bölmelerinde hijyen, çevre koşullarının kontrolü, yavru hayvan sağlığı ile refahı bakımından önemlidir. Bu nedenle bölmelerde zeminin kuru ve drenajının çok iyi olmasına, hayvan hareketlerini kısıtlamayacak ve günlük işlerde zaman kaybını azaltacak şekilde tasarlanmış olmasına dikkat edilmelidir. Yeni doğan yavrularda açlık ve soğuk şokundan kaynaklanan ölümlerin önlenebilmesi için yavruların mutlaka doğumu izleyen ilk 6-12 saat içinde mutlaka yeterli kolostrum almaları sağlanmalıdır. Üretim sistemleri, bölgelere ve hatta illere göre farklılıklar gösterebilmektedir. Bu nedenle, doğru üretim sisteminin seçimi, üremenin başarılı bir şekilde kontrol edilmesi ve yavru ölüm oranlarının sınırlandırılmasında oldukça önemli faktörler olduğu unutulmamalıdır.

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The crude oil percentage and fatty acid profile of turnip rape in continental climate conditions

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Abstract

Türkiye is an importer of vegetable oil and oilseeds. The necessity of mixing biodiesel produced from domestic agricultural products and/or waste vegetable oils into diesel fuel further increases our need for vegetable oils and oilseeds. Therefore, it is important to determine the potential of alternative plant sources that cannot be used in food in terms of supplying raw materials for biodiesel. *Brassica rapa* ssp. *oleifera* is a species with high commercial potential used as industrial seed oil. This study was done in the fall sowing of 2020 in Ankara according to a randomized block design and was established with 4 replications. It was aimed to detect the crude oil percentage and fatty acid profiles of the Tekirdag, Bursa and Tokat origin lines of this species. In terms of study findings, significant differences were found among the lines with regards to the examined traits. Crude oil percentage was detected as 26.93-36.60% in *B. rapa* ssp. *oleifera* lines. It can be stated that local turnip rapeseed lines are rich in unsaturated fatty acids and crude oil percentage, especially in monounsaturated fatty acids such as oleic (16.24-18.65%) and erucic acid (35.66-42.97%), which are the most important factors affecting biodiesel quality, and this species has an important potential as a biodiesel raw material. According to the results obtained from this study, it was detected that Bursa origin Br2 line with Tekirdag origin Br3 and Br6 lines had higher crude oil percentage than other lines. Therefore, it is recommended that these lines be further evaluated for sustainable biodiesel production.

Key Words: *Brassica rapa* ssp. *oleifera, Some quality traits, Oleic acid, Erucic acid*

Introduction

Türkiye is 60-70% dependent on foreign sources for the supply of vegetable oil raw materials. The only agricultural product group in the top 10 among Türkiye's import items is oilseeds and their derivatives. Between 2015 and 2023, 3.041.000-4.320.000 tons of oilseeds (sunflower, soybean, cotton, rapeseed and safflower) and 1.214.000-2.639.000 tons of crude oil were imported. In addition, 1.368.000-2.513.000 tons of oilseed meal are imported from abroad each year (Başalma et al., 2025). The requirement to blend at least 0.5% of biodiesel produced from domestic agricultural products and/or vegetable waste oils into diesel fuel further increases our existing need for vegetable oil and oilseeds (Official Gazette, 2017).

Brassica rapa ssp. *oleifera*, from the *Brassicaceae* family, is among the economically important oilseed crops (Aydin et al., 2024). This species grows as a weed under natural conditions in Türkiye (Kayaçetin et al., 2023). Field mustard (turnip rape), which originates from Asia and Europe, is a species that is more resistant to cold than rapeseed and has annual and biennial genotypes. Its winter genotypes are mostly grown in Europe, while its summer genotypes are grown in Canada, China and India (Aslan, 2023). Seed and seed oil are used as lubricants, in the production of insecticides, in pharmacy, medicine and cosmetics (Li et al., 2021). In addition, seed oil is suitable for biodiesel production and has a high potential for the production of efficient and high-quality biodiesel raw materials (Kayaçetin, 2023). This species, which can grow to 100-150 cm in length, has quadruple bright yellow flowers. According to studies conducted in Türkiye, this species is earlier than brown mustard, rapeseed and black mustard (Kayaçetin, 2019). Its seeds are almost round and are reddish gray to black (Kayaçetin, 2020). The quality characteristics of the oil, such as the ratio of seed oil and fatty acid components, are important factors determining the areas of use of the oil. Although the seeds of this species contain 25-35% fixed oil, they are not appropriate for direct use as human food because of the possible harm to human health owing to the high amount of erucic acid (30-40%) in the fixed fatty acid profile (Poddar et al., 2022), and are among the industrially important oils. The seed oils of this species, which cannot be used as food, can be used as potential low-cost sources for biodiesel production due to high erucic acid.

B. rapa ssp. *oleifera* fatty acid composition and fixed oil ratio may vary depending on genetic and environmental factors (Kayaçetin et al., 2018, Rai et al., 2018; Shyam et al., 2022). Therefore, determining the differences between genotypes allows the selection of genotypes according to the desired characteristics in breeding studies. The goal of this study was to detect the crude oil ratio and fatty acid profile of the seeds of 6 settled lines of the turnip rape lines.

Materials and Methods

In this study, 6 turnip rape settled lines were used as material. Seeds were obtained from the Field Crops Central Research Institute. All turnip rape lines used in this study are strictly winter.

Field trials were carried out in Ankara in the experimental area of the Central Field Crops Research Institute in the autumn growing season of 2019-2020 at 39°12′ – 43°6′ N, 35°58′ – 37°44′ E and 925 m above sea level, based on the randomized block design with four replications. The soils of the trial area are low in organic matter, clayey loam and slightly alkaline. When the climate data were evaluated; the average total precipitation for long years and the trial year was 391.9 mm and 269.6 mm. The max. and min. temperatures and relative humidity values for long years and the trial year were 10.5 °C, 40.4 °C, –17.9 °C, 63.9% and 10.5 °C, 35.5 °C, –12.2 °C, 58.3%, in the same order (Figure 1).

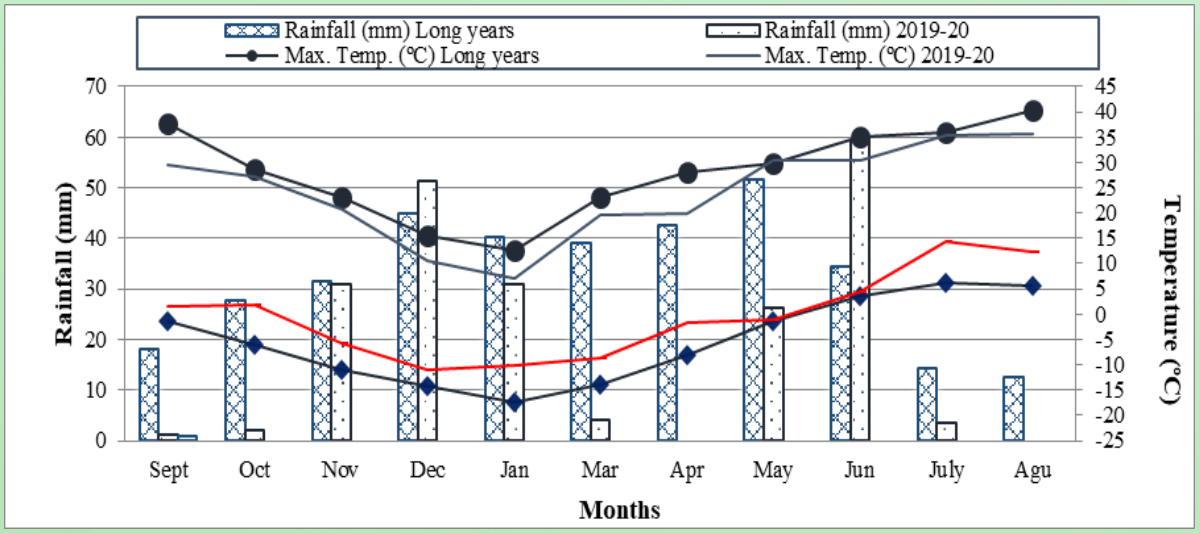


Figure 1. Monthly meteorological data of turnip rape of vegetation period (September to August)

The crude oil ratio and oil profile analyses of turnip rape lines were performed in 4 replications at the DB Agricultural Energy Biofuel Laboratory.

Crude oil percentage (%): The glass beakers to be used during the soxelet extraction process were dried in the drying oven until they reached a constant weight. The tare weight of the beakers was recorded. After the drying process was completed, approximately 5 g of the ground sample was weighed and placed in the soxelet cartridge. After the cartridge was placed in the soxelet extraction system, 140 mL of petroleum ether was added to the flask in the soxelet extraction system and the extraction process was performed. After the extraction process was completed, the extraction flask was kept in the drying oven at 80 °C for 1 hour. After the glass beaker removed from the drying oven was cooled in a desiccator, it was weighed and the amount of oil in the sample was calculated as a percentage (%) (Gölükçü et al., 2016).

Fatty acid profile (%): The fatty acid profile of lines oil in relation to TS 4664 and EN ISO 5508 was determined by gas chromatography-GC (Kayaçetin, 2023).

Data on seed crude oil percentage and fatty acid profiles of turnip rape lines were analyzed using Statistical Analysis Software JMP®13.2.1 using analysis of variance (ANOVA). Differences among means were separated using LSD tests ($p<0.05$).

Results and Discussion

The percentage of moisture in the seed, the percentage of crude oil in the moist seed and dried seed, palmitic, stearic, oleic, linoleic, linolenic, eicosenoic, erucic turnip rapeseed lines are presented in Table 3. Although the percentage of moisture in the seed and the ratio of stearic acid did not show statistically different according to the lines, other examined traits were found to be significant (Table 1). The maximum and minimum crude oil percentage in moist seed were detected 36.60% and 26.93%, in in he same order and in dried seed were determined 38,80% and 28,69% Br2 and Br1 lines, respectively. The maximum palmitic, oleic, linoleic, linolenic, eicosenoic, erucic (2.62, 18.65, 15.33, 11.57, 12.65 and 42.97%) were detected in Br5, Br6, Br5, Br3, and Br1lines, in the same order. The minimum values of 2.23, 16.24, 13.44, 10.10, 11.05, and 35.66 % were noted in Br1, Br1, Br1, Br1, Br3, and Br6 lines, respectively.

Table 1. The crude oil ratio and fatty acid component of turnip rape lines

	Moisture percentage in seed (%)	Crude oil percentage in moist seed (%)	Crude oil percentage in dried seed (%)	Palmitic (C 16:0)	Stearic (C 18:0)	Oleic (C 18:1)	Linoleic (C 18:2)	Linolenic (C 18:3)	Eicosenoic (C 20:1)	Erucic (C 22:1)
Tekirdağ1 pureline (Br1)	5.74	26.93c	28.69b	2.23d	1.08	16.24d	13.44c	10.10c	11.20b	42.97a
Bursa pureline (Br2)	5.71	36.60a	38.80a	2.48b	1.14	16.57cd	14.60b	10.71bc	11.11b	40.56bc
Tekirdağ2 pureline (Br3)	5.65	34.66a	36.58a	2.42c	1.16	17.05c	14.93ab	11.57a	11.05b	39.25cd
Türkiye pureline (Br4)	5.65	30.01b	31.67b	2.49b	1.07	16.30d	13.69c	10.96ab	11.51b	41.55ab
Tokat pureline (Br5)	5.53	30.03b	31.75b	2.62a	1.22	17.80b	15.33a	11.23ab	12.19a	37.21de
Tekirdağ3 pureline (Br6)	5.77	35.88a	37.95a	2.50b	1.21	18.65a	15.26a	11.54a	12.65a	35.66e
Source of variation (%)	3.13	6.00	6.25	1.41	6.13	2.73	2.78	3.35	2.97	3.84
LSD (0.05) = 2.10 (24 df)	ns	**	**	**	ns	**	**	**	**	**

Sharafi et al. (2015) in their study evaluating 20 genotypes of different *Brassica* species including turnip rape, found that the crude oil percentage varied between 21% and 46%; palmitic, oleic, linolenic, linoleic, erucic and stearic acids constituted 89%-94% of the main fatty acids in this species. It has been reported that there are high genetic differences in crude oil percentage and fatty acid compositions among species and genotypes. Rai et al. (2018) in their study examining 5 different turnip genotypes, reported that the crude oil percentage of the genotypes varied between 40.35% and 41.43%. While the linoleic acid content varied between 14.08%-18.18% in turnip rape genotypes, the linolenic acid percentage changed between 9.82%-26.66%. Studies have shown that seed crude oil content and fatty acid composition of genotypes from different *Braasica* species are significantly affected by genotypic and environmental conditions (Da Silva Medeiros et al., 2022; Khan et al., 2022; Kayaçetin, 2023; Sachan et al., 2024).

According to Öğüt and Oğuz (2006), the supply of biodiesel raw materials from non-food oils should be a priority for sustainable biodiesel production. In order to meet both the food and energy demands of the increasing population, the use of fixed oils that cannot be used directly in food for energy purposes is important. It is thought that *B. rapa* ssp. *oleifera* lines, which are not appropriate for direct cooking oil use owing to the erucic acid content in seed fatty acids, can be used appropriately for industrial purposes in terms of fatty acids and can be evaluated as an alternative plant source for biodiesel due to their high adaptation to Türkiye conditions (Kayaçetin, 2023).

B. rapa ssp. *oleifera* lines used in this study exhibited an important level of diversity for the crude oil percentage and fatty acid profile. Although the fatty acid profile of oil turnip limits its use as direct human food, it may pose significant potential for different industrial areas. Based on the results obtained from this study, it was determined that the Bursa origin Br2 line with Tekirdag origin Br3 and Br6 lines had higher crude oil percentage compared to other lines. Therefore, particularly this lines were suggested for further evaluation for sustainable to obtain biofuel.

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Evaluation of the Anti-inflammatory and Anti-hemolytic Potential of Polyphenolic Components of Common Mallow (*Malva sylvestris*)

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Abstract

This work aims at the assessement of anti-inflammatory and anti-hemolytic effect of *Malva sylvestris*. The anti-inflammatory potential was evaluated by the inhibition of protein denaturation method. It was followed by the study of anti-hemolytic potential, based on two methods (haemolysis by hydrogen peroxide (H2O2) and by hypotonic haemolysis). The macerated aqueous extract of *M. sylvestris* (250 µg/ml) exhibited the highest inhibition percentage of BSA denaturation compared to other extracts but it appeared to be slightly lower than the drug diclofenac sodium (80.97±1.23%). On the other hand, the macerated aqueous extract showed more protective power against haemolysis (93.42±3.45%). While it was almost similar to the percentage recorded for ascorbic acid (93.68±3.21%). For the second method, it was observed that the decocted acetone extract of *M. sylvestris* showed a rate of haemolysis inhibition which was the highest (98.09±1.26%) but that it remained slightly lower than aspirin (98.77±0.44%). All of these results showed that *M. sylvestris* extracts have interesting anti-inflammatory and anti-haemolytic potential and therefore have considerable interest as an alternative treatment against inflammatory mechanisms.

Key Words: *Anti-hemolytic, Anti-inflammatory, Malva sylvestris, Polyphenols.*

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Evolution and Transformation of Ethiopian Agriculture: A Review of Historical Trends, Contemporary Challenges, and Future Opportunities

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Abstract

Ethiopia's agricultural sector is pivotal to its economy, employing approximately 85% of the population and contributing significantly to the national GDP. Despite its potential, the sector grapples with critical challenges such as food insecurity, climate change, land degradation, and limited market access. As a result, Ethiopia ranks 101st out of 125 countries on the 2023 Global Hunger Index, with 26.2% of its population undernourished. This review aims to explore the historical trends that have shaped Ethiopian agriculture, critically analyze contemporary challenges, and identify future opportunities for transformation. The findings highlight that policy shifts and technological advancements are essential for overcoming existing barriers. Key opportunities for enhancing agricultural productivity include the adoption of climate-smart practices, technological innovations, improved market access, sustainable land management, and necessary policy reforms. By addressing these challenges and leveraging opportunities, Ethiopia can achieve a more productive and sustainable agricultural system that supports food security and rural development. The commitment of all stakeholders is crucial for realizing these transformations in Ethiopian agriculture.

Keywords: *Ethiopian agriculture, food security, climate change, future opportunities, historical trends, sustainable development, agricultural transformation.*

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Optımızıng The Constructıve Parameters Of The Combıned Plough That Increases Productıvity In Graın Farmıng

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Abstract

Currently, one of the leading areas of food security in the world is grain growing.Our goal is to develop grain growing on slopes.For the first time, the technological process of applying fertilizer in equal amounts to the soil on slopes and the constructive design of the working bodies, improved in the direction of obtaining quality grain in the cultivation of grain crops and increasing productivity, ensures the equal and quantity of sowing on sloping places by placing a "equal fertilizer spreader" working body at the outlet of the fertilizer pipe.The mineral fertilizer spreader is technologically and constructively new.The invention was patented by the Intellectual Property Agency of the Republic of Azerbaijan under document number F20240021.The efficient and optimal technological constructive parameters of the mineral fertilizer spreader have been substantiated.The optimal values were selected by building mathematical tables based on the parameters of the main parts of the newly created "equal fertilizer spreader".In a field test of the "equal fertilizer spreader" designed based on optimal values, the even distribution of urea fertilizer under the plow was 92%, double superphosphate was 94%, and potassium chloride was 93%.

Key words: equal fertilizer spreader,combined pluogh,constructive parametrs,mineral ferilizer,even distribution

Introductıon

Since the vast majority of Azerbaijani soils are carbonate, when phosphorus fertilizers are applied to such soils, phosphorus compounds combine with iron, aluminum, etc. in the soil, becoming insoluble compounds and poorly absorbed. In order to increase the efficiency of phosphorus fertilizers in these soils, it is of great importance to apply them under deep plowing as the main fertilizer. When the annual norm of phosphorus is high, it is advisable to apply part of it under plowing as the main fertilizer, and the rest together with sowing and as a feeding during the vegetation period, and to deeply bury it. It is useful to apply half of the annual norm of potassium fertilizer under plowing as the main fertilizer, and the rest as a feeding during the vegetation period. When calculating the usefulness of fertilizers, it is necessary to take into account not only their direct effect on the soil in the year of application, but also their effect in subsequent years, improvement of product quality, and increase in soil fertility (Abbasov İ.D.2011.,Alakbarov F.2016.).

Currently, various methods are used to apply fertilizers under plowing. At the same time, in our republic, mineral fertilizers are spread on the surface of the soil after harvesting with "Amazone ZA M" brand centrifugal disc fertilizer spreaders. Immediately after sowing, plowing is carried out with a plow so that the spread fertilizers fall under the soil. The operation is carried out in such a technological form.

The working width of the spreader always exceeds the design dimensions of machines with centrifugal working bodies, which is one of their main advantages. In this case, the uniformity of the spreader usually works with a previously unknown overlap of adjacent passages. The impossibility of strictly fixing the optimal working width is one of the main disadvantages of centrifugal working bodies of fertilizer spreaders. With changing operating conditions, the optimal working width determined experimentally for a particular type of fertilizer is limited to this. In addition, the actual working width of the machine does not always correspond to the optimal sowing, which leads to changes in speed and uneven application. It follows from this that the agro technical indicators of the centrifugal working bodies of the machines are interdependent and do not remain constant during operation due to the influence of many factors (Alakbarov J, al.et.2001)

In order to obtain high-quality grain and increase productivity in grain farming, the technology of applying equal amount of fertilizer to the soil and the justification of the design and technological parameters of the combined tillage were carried out, and laboratory and farm tests were carried out on a newly created experimental facility.

As you can see from the, two ATP-2 fertilizer spreaders are installed on the plough.The movement of the spreaders apparatus is provided by the support wheel of the plough.Fertilizer spreading rate is adjusted by changing wheels (Qurbanov H.N., 2023).

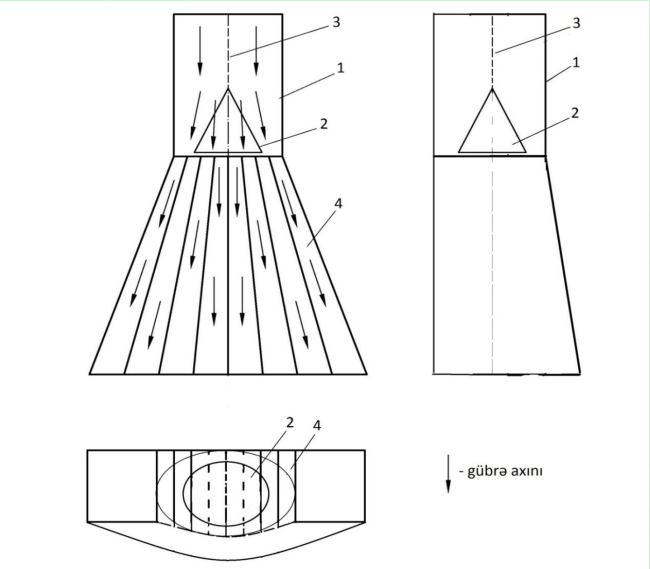


Fig.1 Equal spreader

1 - main cover, 2 - pendulum cone, 3 - chain, 4 - fertilizer channels

The field test of the combined plough is shown in figure 3.The combined plough consists of two ATP-2 fertilizer spreaders mounted on a SP-12 4-body plough manufactured in Turkey.Fertilizer devices get the movement from the support wheel of the plough through chain transmissions.Fertilizer spreaders, driven by the support wheel, deliver the fertilizer under the plow through four fertilizer tubes fig.2.



Figure 2 Laboratory test

A equal spreader is attached to the outlet of the pipes to ensure equal spreading of fertilizers.The use of the combined plough completely reduces the operation of spreading fertilizer with fertilizer spreaders before the plowing operation, the costs and labor spent on it, at the same time, high efficiency of the use of fertilizers is ensured, equal distribution the fertilizer under the soil prevents its loss, ensures its equal spreading, etc figure 1.In addition, time is significantly saved and operations can be performed in a short time (Qurbanov H.N., 2022).



Fig. 3 Field test

Material And Methods

The dimension parameters of the pendulum cone, which is the working body of the equal scatterer, are taken as the basis of the cone (tg γ) angle, cone height (h), cone diameter (d), distance between the cone and the wall (Z), and the charge distance from the cone to the partitions (h1) (OST. 70.71 – 2000);(Melnikov S.V. al.et.,1980).The main parameters of the subject on spreading width (D) were calculated and are given in Table-1. Based on mathematical calculations, the parameters of the working subject were selected spreading width (D). According to the conditions of the one-factor experiment, the distance between the cone and the wall (Z) and the charge distance from the cone to the partitions (h1) were taken with fixed numerical values by obtaining mathematical dependencies.

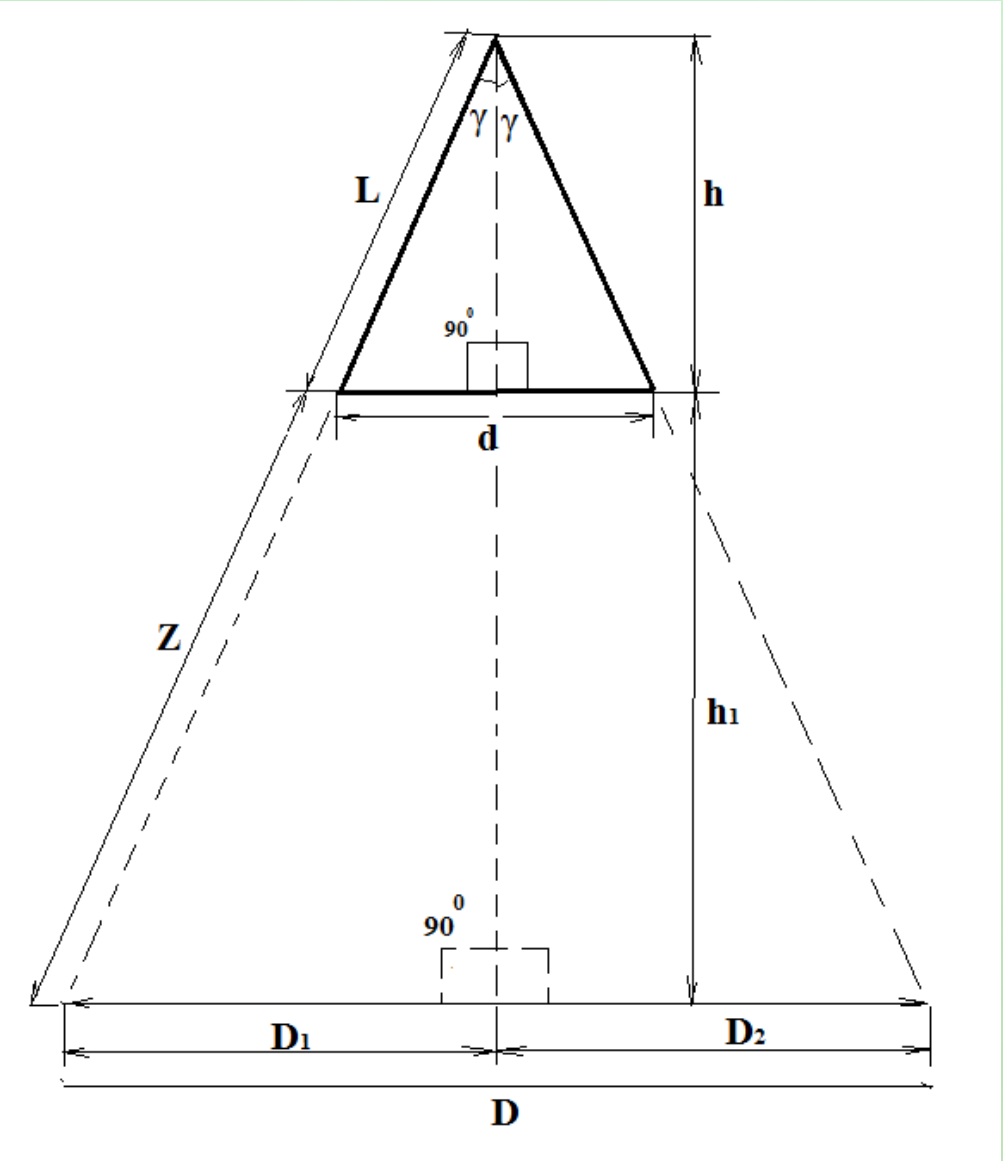


Figure 4 Dimensions and scattering parameters of the cone

Figure 4 is based on mathematical geometric calculation, based on the Pythagorean theorem of a right triangle, we can write the following formulas,

$L^2 = h^2 + (d/2)^2$; ..... (1)

$(L+Z)^2 = (h+h_1)^2 + D_1^2$; .....(2)

$D_1^2 = (L+Z)^2 - (h+h_1)^2$; .....(3)

$D_1 = \sqrt{(L+Z)^2 - (h+h_1)^2}$; ..... (4)

$D_2 = \sqrt{(L+Z)^2 - (h+h_1)^2}$; ..... (5)

$D = D_1 + D_2$; ..... (6)

$d = \sqrt{L^2 - h^2}$; ..... (7)

Tabel 1.Optimizing cone size parameters

№	distribution angle, tg γ	h, height , sm	d, diameter, sm	cone-to-wall clearance distance (Z), sm	h_1, distribution distance from the cone to the partitions, sm	D, spread width, sm
1.	20	3	2.18	1	25	20.38
2.	21	3	2.30	1	25	21.49
3.	22	3.5	2.83	1	25	23.03
4.	23	3.5	2.97	1	25	24.19
5.	24	4	3.56	1	25	25.82
6.	25	4	3.73	1	25	26.87
7.	26	4.5	4.39	1	25	28.77
8.	27	4.5	4.59	1	25	30.06
9.	28	5	5.32	1	25	31.90
10.	29	5	5.54	1	25	33.26
11.	**30**	**5.5**	**6.35**	**1**	**25**	**35.20**
12.	31	5.5	6.61	1	25	36.65
13.	32	6	7.49	1	25	38.74
14.	33	6	7.79	1	25	40.26
15.	34	6.5	8.77	1	25	42.49
16.	35	6.5	9.10	1	25	44.11
17.	36	7	10.17	1	25	46.50
18.	37	7	10.55	1	25	48.23
19.	38	7.5	11.72	1	25	50.78
20.	39	7.5	12.15	1	25	52.64
21.	40	8	13.44	1	25	55.38

Fertilizer application rate (G), slope inclination (α°) were taken as the main factors influencing the uniform distribution of fertilizer to the combined plough.The sequence of experiments in the experiment planning matrix was determined using a table of random numbers.

In order to determine the rate of fertilizer spreading, the data of the Ministry of Agriculture for the Goy-gol region and the rate of spreading of laboratory research were selected: the upper limit for changing the movement speed of the aggregate was taken as 1.66 m/s.The researches were carried out in October, when the main rate was applied during the preparation of the soil for the planting of autumn cereals in 2020-2021.

In the flow pipe of the fertilizer spreader, a conical pendulum is placed in front of the flow to spread the inclined flow evenly.A section consisting of a partition divided into eight equal parts is prepared.Fertilizer is applied to the rear part of the 35 cm wide ladder by dividing the particles scattered from the conical pendulum into eight equal parts.

Results And Discussion

Mathematical models were constructed on the obtained parameters, calculating the percentage of equal dispersion in the direction of different angles in the laboratory conditions of a smooth disperser.

Reliability of distribution according to the technological scheme can be achieved under the condition that the selection of structural dimensions of the smooth spreading part allows optimal fertilizer distribution (Pyataev M.V.,2010).

Due to the fact that the working width of the cranberry in the plough trunk is 35 cm, the required spreading width D=35.2 cm, the angle of the cone tg γ =30 degrees, cone height h = 5.5 cm, and cone diameter d = 6.35 cm are taken from Table 1.The clearance distance between the cone and the wall Z =1 cm and the charge distance from the cone h_1 = 25 cm are taken as fixed values.

In order to verify the reliability of the control studies, to improve the proposed design of the machine and to justify its operating modes, field studies are determined, which ensures the spreading of fertilizers in the field.

Phosphorous and potassium fertilizers are not soluble in water, so the penetration area in the soil is small.However, since nitrogen-containing fertilizers are water-soluble, the penetration area in the soil is large.The spread of mineral fertilizers in the soil, the penetration of phosphorus substance from the place where it falls is 5.6 cm, and potassium substance is 6 cm (Klyatis L.M.,et.al., 1979);(Bagirov B. et.al.,2018).If we accept the penetration area of granular

particle as circular, then we can calculate the penetration area of phosphorus and potassium particle by mathematical method.

Penetration area of the phosphorus particle

$S_p = \pi r^2 = 3.14*2.8^{\ 2} = 24.62\ sm^2$

Penetration area of potassium particle

$S_k = \pi r^2 = 3.14*3^{\ 2} = 28.26\ sm^2$

Since the width of the plough cranberry is 35 cm, let's select the number of partitions that divide the distribution area in the size of the width of the cranberry.

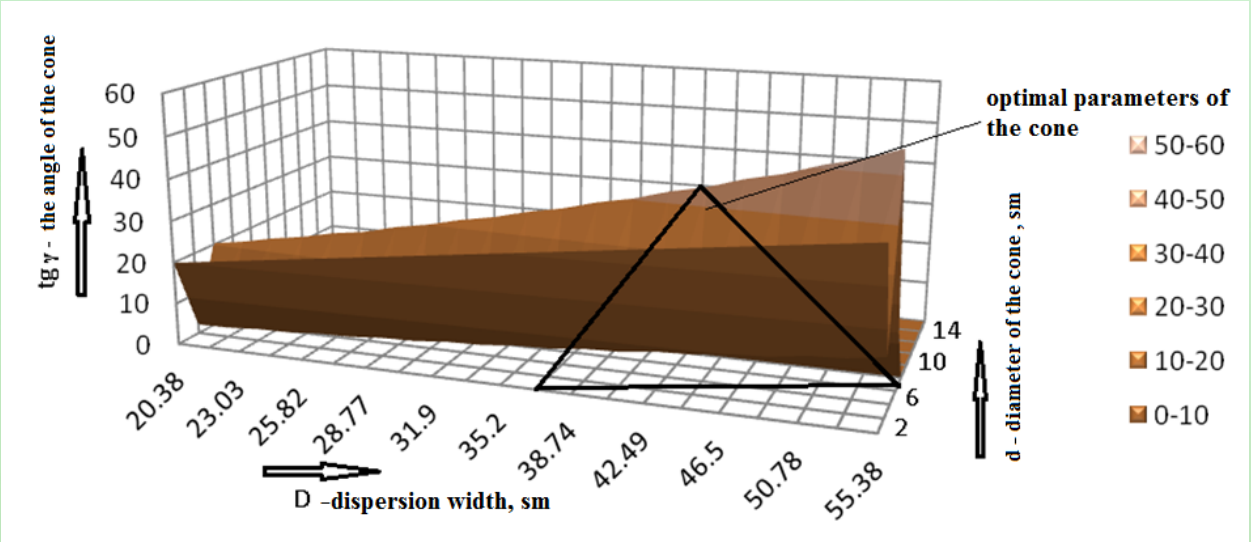


Fig. 5 Optimization graph of cone parameters

Table 2 Selection of the optimal value of the numerical content of partitions according to the penetration area of fertilizer particles

№	Partitions number, ps	number of channels, ps	The distance between partitions, sm	Channel width,sm	Area of a canal, sm^2	Penetration area of potassium particle, sm^2	Penetration area of the phosphorus particle, sm^2
1	4	5	8.75	5.5	48.13	28.26	24.62
2	5	6	7.0	5.5	38.5	28.26	24.62
3	6	7	5.83	5.5	32.1	28.26	24.62
4	**7**	**8**	**5.0**	**5.5**	**27.5**	**28.26**	**24.62**
5	8	9	4.38	5.5	24.09	28.26	24.62
6	9	10	3.89	5.5	21.4	28.26	24.62
7	10	11	3.50	5.5	19.25	28.26	24.62
8	11	12	3.18	5.5	17.5	28.26	24.62

Partitions, which are one of the structural main parts of the smooth spreader, create channels, and the optimal value of the number content of the penetration areas of fertilizer particles is selected from table 2.The number of partitions is 7, the number of channels is 8, the area of one channel is 27.5 cm^2.

In mountain agriculture, one of the main issues is to apply mineral fertilizers in equal amount to the soil before sowing the grain seeds. Mineral fertilizers containing phosphorus and potassium, distributed evenly under the soil, are easier to be absorbed by plants. From our research, it is clear that if the soil is cultivated at a depth of 18 cm, there is better distribution.

The nutritional area of each grain seed buried in the soil is provided with 90-97% nutrients. Even distribution significantly affects the development of the plant stem, its height, and the quality of the grain.

Analyzes showed that the fertilizer spreaders for the application of mineral fertilizers do not meet the agro technical requirements by unevenly distributing the fertilizers in the cultivated area, which leads to uneven development of plants and yield loss. Increasing the efficiency of the use of mineral fertilizers can be achieved by using technical means developed on the basis of scientifically based technological and technical solutions that ensure adaptation of the processes to the requirements of cultivated plants in terms of norms and types of mineral nutrition. The use of a combined plough completely reduces the operation of spreading fertilizer with fertilizer spreaders before the

plowing operation, the costs and labor spent on it, saving time and ensuring that the operations are performed in a short time. Distribute equally fertilizer under the soil is environmentally friendly and prevents fertilizer loss. Compared to centrifugal disc type machines, the most promising machines for application of solid mineral fertilizers are made with a combined plough, which ensures smooth spreading by reducing the unevenness of the horizontal, longitudinal and, accordingly, total spreading by 15-20%.The design of the combined plough has been developed, including: frame, bunker, sowing apparatus, equal spreader, motion transmissions, and plough.
We consider the combined plough to be a convenient technical tool for farmers.

Conclusions

1. The optimal size parameters and location of the pendulum cone, which is the working body of the equal fertilizer spreader, have been determined. The angle of the cone was tg γ=30°, the height was h=5.5 cm, the diameter was d=6.35 cm, the gap between the cone and the wall was Z=1, the distribution area from the cone to the partitions was h_1=25 cm, and the scattering width of the particles from the cone was D=35.2 cm.
2. The optimal number of partitioned fertilizer channels with an equal amount of fertilizer spreader and a working body has been determined. The number of partitions was 7, the number of fertilizer channels was 8, the distance between the partitions was 5 cm, the width of the channels was 5.5 cm, and the area of one channel was 27.5 cm^2.
3. As a result of selecting the optimal parameters, the "equal fertilizer spreader" evenly distributed granular fertilizers under the soil, and the urea fertilizer was 92.0%, double superphosphate - 94.0%, and potassium chloride - 93.0%.

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Effects of sexed semen on fertility and sex ratio of calves in indigenous Arsi Cattle at Adami Tulu Agricultural Research Center

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Abstract

An on-station study was conducted at Adami Tulu Agricultural Research Center during 2021 to 2022/23 breeding season to evaluate the effect of sexed semen on fertility rate of cows, number of services per conception (NSPC), conception rate, sex ratio of calves born and the economics of using sexed semen in indigenous Arsi cattle. For evaluation purpose indigenous Arsi Breed cattle were selected from nucleus herd maintained at on station based on their parity, body condition and reproductive history and assigned to one of the following treatments. Animals in Treatment 1 were inseminated with conventional semen and Treatment 2 were inseminated with sexed semen. They were synchronized for estrus by injecting PGF2α hormone, whereas, those animals exhibited the sign of heat naturally were inseminated directly. Heat was detected by herdsmen in the early morning, mid-day, early evening and at nighttime. Standard procedure of semen handling and insemination was implemented during the study. Pregnancy diagnosis was performed by rectal palpation after 90 days of insemination. There was no significant difference (P>0.05) in NSPC between the treatments and the overall mean NSPC was 1.23±.049. There was no significant difference (P>0.05) in pregnancy rate between treatments. The pregnancy rate was 71% and 56.4% for conventional and sexed semen, respectively. The mean conception rate was 57.9% and 44% with conventional and sexed semen, respectively. There was a significant difference (P<0.05) in sex ratio of calves born between treatments. The average female calf obtained was 50% and 85% for conventional and sexed semen, respectively. The overall advantage of using sexed semen was 769,532 ETB and 15,390.64 ETB advantage per unit of sexed semen used. Sexed semen can be used as alternative artificial insemination technology for Arsi breed cows to produce more female calves for herd replacement. On-farm evaluation and demonstration of using sexed semen technology is important in potential areas suitable for dairy production.

Key words: *Sexed semen; conception rate; sex ratio*

Introduction

Naturally, it has been reported that the sex ratio among the mammals is 50:50 towards the birth of male and female offspring. However, depending on the demand of the livestock farmers, researchers have tried over the years to alter the ratio favoring the birth of a particular sex. Several such studies have considered different hypotheses viz. time of insemination, provision of different types of feeds and minerals, alteration of vaginal and uterine pH, use of sexed semen (De Graaf *et al.,* 2009), uses of certain chemicals. Observations of study by Khan *et al.,* (2012) indicated that alteration of sex ratio in cattle is financially attractive. In beef cattle production it can result in the birth of bull calves which have enhanced growth rate vis-a-vis those of the cow calves of the same age (Keane and Drenna, 1990). In contrary to the beef farms, dairy farmers are generally interested in female calves to maintain their herd. Furthermore, the requirement for a fewer male to female sex ratio (i.e., lower sex ratio) in dairy cattle is important when the herd replacement rates are high which can also help in improving the selection intensity (Badinga *et al,* 1985).

Most of the studies conducted on the sex ratio of calves produced by different insemination technologies have reported contradictory results. Birth of female calves is important especially among the dairy farmers or those who are associated with the dairy industry (Xu *et al.* 2000). Artificial insemination (AI) has been one of the widely accepted biotechnology that has revolutionized the optimum use of good quality sires. However small and medium scale dairy farms in different areas of Ethiopia have been complaining about more numbers of male calves being born following artificial insemination (AI) (Bekele, 2005, Frehiwet *et al.,* 2014) similar observations have also been reported by Skjervold and James, (1979) and Xu *et al.* (2000).
S. A. Holden and S. T. Butler, 2018 indicated that Sex-sorted semen is a revolutionary technology for cattle breeding. Utilization of sexed semen can increase the efficiency of both dairy and beef production, increase farm profitability and improve sustainability of cattle agriculture.

The use of sex-sorted semen in both dairy and beef production allows predetermination of calf sex with up to 90% reliability. More recent studies have demonstrated that sexed semen can be successfully used in both heifers and multiparous cows, (Butler *et al.,* 2014; Xu, 2014). Nevertheless, no research has been conducted on the effect of using sexed semen on the fertility of cows and sex ratio of calves in Arsi cattle breed. This study was conducted the following objectives:

Objectives

- To evaluate the effect of inseminating cows with sexed semen on the number of services per conception and conception rate and sex ratio of calves born
- To evaluate the economic benefit of using sexed semen for dairy producers

Materials and methods

Study area

The study was conducted at Adami Tulu Agricultural Research Center. The center is located at 167km south of Addis Ababa and situated at latitude of 7^0 9` N and $38^0$7`E longitude in semi-arid middle rift valley of Ethiopia. The area is situated at 1500 meters above sea level and the soil type of the area is fine, sandy loam and clay in the proportion of 34:48:18 respectively. The average annual rainfall is 760mm. The minimum and maximum temperature are 12.6 and 27^0c, respectively (ATARC, 2003).

Materials used

Experimental animals, sexed and conventional semen, liquid nitrogen, AI Gun, AI sheath, arm length glove and concentrate feeds. Sexed semen, Progeny tested frozen semen of Holstein Frisian sires of Worldwide Sires® (WWS), and Conventional frozen semen of Holstein Friesian sire reared at LDI were used.

Experimental animals

A total of 70 Arsi cows and heifers were selected based on several traits (parity, body condition, milk yield, mothering ability, free from reproductive diseases). Breeding was done from 2021/22 to 2022/23 breeding season.

Estrus synchronization: 2ml Lutylase hormone was injected to each cow after detecting the presence of responsive corpus luteum (CL) through rectal palpation. Animals exhibited signs of heat naturally were inseminated directly without the injection of hormone.

Heat detection: Cows were monitored by herdsmen and night guards for signs of heat (early in the morning, at daytime and late in the evening).

Breeding: Cows showing signs of estrus naturally or through administration of Synchromate hormone were inseminated with progeny tested sexed semen (obtained from Worldwide Sire ® (WWS) and conventional semen (obtained from LDI).
A standard semen handling and insemination procedure as recommended by IAEA (2005) was used to inseminate the animals. Cows noted in heat in the morning were inseminated in the afternoon and those identified in the afternoon were inseminated the next morning based on the “AM- PM guideline” (Peter and Ball, 1995).

Experimental design

The experimental animals were blocked based on their parity, age and body weight and assigned to one of the following treatments:
Treatment 1=Conventional Semen
Treatment 2= Sexed Semen

Collected data

Number of animals synchronized (treated with PGF2α), number of animals that come to heat, number of animals inseminated, number of services per conception, number of animals pregnant , number of calves born, sex ratio of calves at birth , General health data of the cows, cost of semen and other costs.

Pregnancy rate was calculated using the following formula:

$$\text{Pregnancy } Rate\ (\%) = \frac{Number\ of\ pregnant\ animals}{total\ number\ of animals\ inseminated} X100$$

Conception rate was calculated using the following formula:

$$Conception\ Rate\ (\%) = \frac{Number\ of\ pregnancies}{Number\ of\ inseminations} X100$$

Economics of sexed semen

Economics of using sexed semen was estimated by using simple and flawed model of the economics of sexed semen recommended by Fetrow J. (2007). The cost of both sexed and conventional semen per conception was considered as cost incurred. The sale price of 3-month male calves and yearling female heifers were estimated by dairy producers and individuals having experience in buying and sale of crossbreed animals in the area. Additionally the rearing cost of female calves until yearling age was estimated both by experienced dairy producers and technically by researchers. The profit of female claves is calculated as the difference between the selling price minus rearing cost of heifers (labor cost, price of milk consumed by heifers, veterinary costs, and costs of concentrate and roughage feeds. Finally, the overall advantage of sexed semen and advantage per unit of sexed semen was calculated as follows:

Advantage of sexed semen = Net income of sexed semen – Net income of conventional semen

$$\text{Advantage per unit of sexed semen used} = \frac{\text{Overall advantage of sexed semen}}{Total\ unit\ (dose)\ of\ sexed\ semen}$$

Data analysis

Collected data were entered into MS excel and data were analyzed using descriptive statistics and Chi square test. Significance was declared at P<0.05.

Results and Discussions

Number of services per conception

The result indicated that there is no significant difference in services per conception (NSPC) between the treatments and the overall mean NSPC was 1.23±.049 (Table 1). The current result is in line with reports by different authors who reported services per conception ranges from 1.06 to 2.6 (Million *et al.,* 2006; Genzebu *et al.,* 2016).

Table 1. Average number of services per conception of Indigenous Arsi cows inseminated with conventional and sexed semen

Treatment	N	Mean ± SE	P value.
Conventional semen	31	1.23±.076	
Sexed semen	39	1.28±.082	0.624
Total	70	1.26±.056	

Pregnancy rate

The result indicates that there is no significant difference in pregnancy rate between treatments (Table 2). The pregnancy rate is 71% and 56.4% for conventional and sexed semen, respectively. The current result is higher than the pregnancy rate reported by Seidel and Schenk (2002) who reported 43 to 62% and 31 to 42% pregnancy rate for conventional and sexed semen in different field experiments. The difference might be due to the environment in which the trial was conducted since our experiment was conducted at on station and the previous study was conducted on-farm.

The current result on pregnancy rate by using sexed semen is comparable to the results of Cerchiaro *et al.* (2007) who reported pregnancy rate of 51% for sexed semen in the field study conducted on Holstein Friesian cows in Italy.

Conception rate

The mean conception rate is 57.9% and 44% for conventional and sexed semen, respectively. The conception rate for sexed semen was lower than conventional semen. Norman *et al.* (2010) indicated that the process of sorting sperm cells reduces the conception rates in dairy cattle. The conception in current study was higher than the result reported by Norman *et al.* (2010) who reported the conception rates of 30 and 25% by using conventional and sexed semen.

Table 2. Pregnancy rate of Indigenous Arsi Cows inseminated with conventional and sexed semen

Treatment	Parameter	Pregnancy rate		Total	P value
		Positive	Negative		
Conventional semen	N	22	9	31	
	%	71	29	100	
Sexed semen	N	22	17	39	0.0158
	%	56.4	43.6	100	
Total	N	44	26	70	
	%	62.9	37.1	100	

The result of conception rate observed in the current study was lined with the report of Anonyms (2020) who reported the conception rate of (50.2% vs. 60.3%, for sexed and conventional semen, respectively. In contrast to this Oikawa K, *et al.* (2019) and Sahereh Joezy-Sh. e*t al.* (2017) reported 47.3% and 48.3% conception rate by using sexed semen and 63.8% using conventional semen in Holstein cows. The difference might be due to the number of data taken and easily accessibility of fresh processed semen we use imported sexed semen.

Sex ratio of calves born

The result indicated that there is a significant difference (P <0.05) in sex ratio of calves born between treatments (Table 3). The rate of obtaining female calf was 85% and 50% for sexed semen and conventional semen, respectively. Albert De Vries (2010) indicated that sexed semen with relatively more X- chromosome bearing sperm had a greater chance to result in female calf. It is justifiable that sexed-sorted semen produces a greater number of single sexes as the desire of the producers, and we used X-chromosome sorted semen.

The current result on calve sex ratio was in line with previous reports on sexed semen between 85 and 91% by Tubman *et al.* (2004); Borchersen & Peacock (2009); DeJarnette *et al.* (2009); Norman *et al.* (2010). Norman *et al.* (2010) and Alemayehu and Girma (2019) reported 48% and 42.9% female calf ratio by using conventional semen, respectively.

Table 3. Sex ratio of calves born from Indigenous Arsi Cows inseminated with conventional and sexed semen

Treatment	Parameter	Sex of calves born		Total	P value
		Female	Male		
Conventional semen	N	11	11	22	
	%	50	50	100	
Sexed semen	N	17	3	20	0.018
	%	85	15	100	
Total	N	28	14	42	
	%	66.7	33.3	100	

Economics of sexed semen

The overall advantage of sexed semen and advantage per unit of sexed semen used were calculated and the result revealed that the use of sexed semen is economical. The overall advantage of using sexed semen was 769,532 ETB and 15,390.64 ETB advantage per unit of sexed semen used. The current result is contrast with the findings of De Vries (2008) who reported that the use of sexed semen across all heifers is not necessarily profitable. The difference might be due to the difference in conception rate as they reported lower conception rate of sexed seme than the current finding.

Conclusions and Recommendations

The number of services per conception was similar across the types of semen used for insemination. Conception rates have a positive correlation with the number of pregnancies show similar trends with pregnancy rate across treatments.

Use of sexed semen is economical and has an advantage over conventional semen.
Maximum care must be taken by Artificial inseminators and farm owners on using sexed semen to attain best conception rate.
Sexed semen can be used as technological intervention for dairy farms who needs more female calves for herd replacement. Use of sexed semen needs to be evaluated and demonstrated at on farm level in potential areas suitable for dairy production.

Table 4. Economics of conventional and sexed semen used in Indigenous Arsi cows

Parameter	Unit	Conventional semen	Sexed semen
Conception rate	%	71	44
Amount of semen used	Number	38	50
Semen price	ETB	14	3,000
Total cost of semen	ETB	532	150,000
% of heifers	%	50	85
Number of heifers	Number.	11	28
% of bulls	%	50	15
No of male calves	Number.	11	14
Price of heifer	ETB	80,000	80,000
Cost to rear a heifer	ETB	27,000	27,000
Profit per heifer	ETB	53,000	53,000
Sale price of a bull calf	ETB	6,000	6,000
Income from heifers	ETB	583,000	1,484,000
Income from bulls	ETB	66,000	84,000
Total income	ETB	649,000	1,568,000
Total income minus semen cost	ETB	648,468	1,418,000
Advantages of sexed semen	ETB	769,532.0	
Advantage per unit of sexed semen used	ETB	15,390.64	

Acknowledgement

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The Antioxidant Activity of *C. tournefortii* Fruits and Leaves

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Abstract

Celtis species are known to be used in traditional medicine for treating diseases such as edema, hypertension, kidney disorders, diabetes, cancer, and joint pain. In this study, the antiradical (DPPH), reducing power (CUPRAC and FRAP) activities, and total phenolic and flavonoid content of methanol extracts from *Celtis tournefortii* fruits (CTM) and leaves (CTY) were evaluated. The total phenolic content in *C. tournefortii* fruit and leaf extracts was determined to be 2.0±0.10 mg GAE/g and 18.63±1.52 mg GAE/g, respectively. The flavonoid content was calculated to be 11.71±0.14 mg KE/g in CTM and 21.93±1.53 mg KE/g in CTY. It was observed that the radical scavenging activity was higher in *C. tournefortii* leaf extracts. Additionally, the reducing power of Fe^{3+} and Cu^{2+} was also relatively higher in the *C. tournefortii* leaf extract. The current study demonstrated that *C. tournefortii* fruits and leaves contain bioactive compounds and possess antioxidant activity. Although the antioxidant activities of the extracts were found to be low, the presence of radical scavenging and reducing power was detected. The findings emphasize the potential of the plant *C. tournefortii*, commonly known as dardağan, as a functional food component and a natural antioxidant source.

Keywords: *Celtis tournefortii, Antioxidant, Dardağan, Çitlembik, Phenolic compounds.*

C. tournefortii Meyve ve Yapraklarının Antioksidan Aktivitesi

Özet

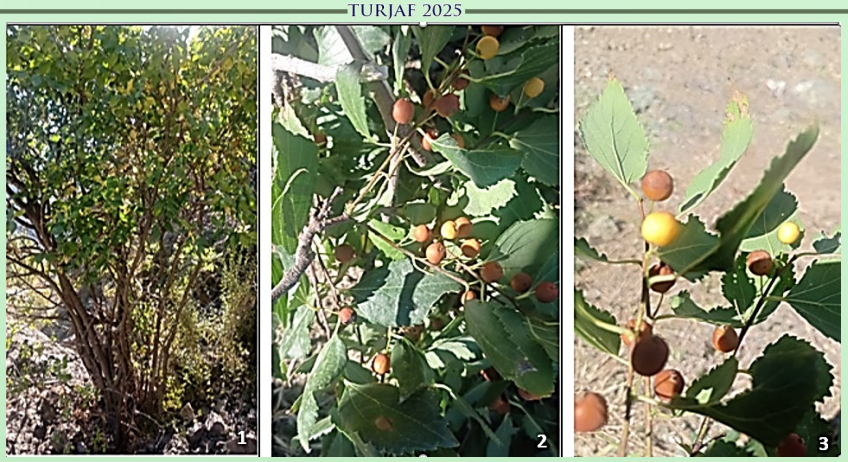
Celtis türlerinin halk arasında ödem, hipertansiyon, böbrek rahatsızlıkları, diyabet, kanser ve eklem ağrıları gibi hastalıkların tedavisinde kullanıldığı bilinmektedir. Bu çalışmada *Celtis tournefortii* meyve (CTM) ve yapraklarının (CTY) metanol ekstraklarının antiradikal (DPPH), indirgeme gücü (CUPRAC ve FRAP) aktiviteleri, toplam fenolik ve flavonoid madde miktarları değerlendirilmiştir. *C. tournefortii* meyve ve yaprak ekstraklarında toplam fenolik madde miktarı sırasıyla 2.0±0.10 mg GAE/g ve 18.63±1.52 mg GAE/g olarak belirlendi. Flavonoid madde miktarı CTM'de 11.71±0.14 mg KE/g iken CTY'de 21.93±1.53 mg KE/g olarak hesaplandı. *C. tournefortii* yaprak ekstraklarda radikal giderme aktivitesinin daha yüksek olduğu görüldü. Ayrıca Fe^{3+} ve Cu^{2+} indirgeme gücünün *de C. tournefortii* yaprak ekstraktında nispeten daha yüksek olduğu görüldü. Mevcut çalışmada *C. tournefortii* meyve ve yapraklarının biyoaktif bileşen içerdiğini ve antioksidan aktiviteye sahip olduğunu gösterdi. Ekstrakların antioksidan aktiviteleri düşük bulunmasına rağmen radikal giderme ve indirgeme gücünün var olduğu tespit edildi. Elde edilen bulgular dardağan olarak isimlendirilen *C. tournefortii* bitkisinin fonksiyonel gıda bileşeni ve doğal antioksidan kaynağı olarak potansiyelini vurgulamaktadır.

Anahtar kelimeler: *Celtis tournefortii, Antioksidan, Dardağan, Çitlembik, Fenolik bileşen*

Giriş

Bitkiler birincil metabolizmalarını yaşamsal aktiviteleri için kullanılırken, ikincil metabolizmanın sonucu üretilen metabolitleri de stres durumlarında kullanırlar. Bitkiler tarafından üretilen ikincil metabolitler canlılarda birçok biyolojik aktivitede yüksek fayda sağlayan bileşiklerdir (Baran ve Keskin 2023). Bitkiler tarafından kimyasal savunma mekanizması olarak üretilen biyoaktif bileşikler antioksidan, antimikrobiyal ve antitümör etkiler gösterirler (Keser ve ark., 2017.

Ilıman ve tropikal iklimlerde yetişen dağdağan (*Celtis tournefortii* Lam.), Türkiye'de çeşitli kullanım alanlarına sahip bir meyve türüdür. Kendirgiller (*Cannabaceae*) familyasına ait olan *Celtis*, her yıl yapraklarını döken ve orta boy ağaçlardan oluşan bir bitkidir (şekil 1). Bu bitki, yöresel olarak dağan, dağdağan, dardahan, çitemik, çitlembik, davin, gıngırez, ılıç, melengiğ, yabani kiraz veya çıtlık gibi adlarla bilinmektedir (Yaltırk 1998; Yücedağ ve Gültekin 2008, Demirdağ 2023).



Şekil 1. *Celtis tournefortii* (Dardağan) Bitkisi (1: *Celtis tournefortii*'nin ağaç formu, 2,3: *Celtis tournefortii*'nin yaprak ve meyveleri)

Celtis tournefortii Türkiye'de kendiliğinden yetişen dört çitlembik türünden birisidir. Doğu çitlembiği olarak da bilinen *dardağan*, yaprak döken ve boyu 2 ila 3 m'ye kadar büyüyebilen bir ağaç türüdür. İlkbahar aylarında çiçek açar ve çalılıklar, kayalık yamaçlar ve ormanlarda kendiliğinden büyür. Eylülden ekime kadar meyve veren bu ağacın meyveleri küçük nohut büyüklüğünde, çekirdekli ve fıstık tadındadır. Başlangıçta açık kahverengi olan meyveler olgunlaştıkça koyu kırmızımsı veya sarımtırak kırmızı renk alır (Özrenk ve ark., 2012; Keser ve ark., 2017; İkinci, 2018). Dardağan meyveleri başta Türkiye olmak üzere Yunanistan, Irak, Azerbaycan, Ukrayna gibi ülkelerde yaygın olarak tüketilir.
Farklı *Celtis* türleri ödem, hipertansiyon, böbrek rahatsızlıkları, diyabet, kanser ve eklem ağrıları gibi hastalıkların tedavisinde kullanılmaktadır (Gecibesler, 2019). Ayrıca *C. tournefortii* tohumları böbrek kumuna karşı, yaprakları mide ağrısında, kanamayı durdurmada, yatıştırıcı amaçlarda ve sindirimi kolaylaştırmakta kullanılmıştır (Keser ve ark., 2017). Bazı *Celtis* türlerinde yapılan çalışmalar flavonoid, kumarin, fenolik, tanen ve alkaloid gibi bileşiklerin bu türlerde bulunduğunu bildirmiştir (Kim ve ark., 2005; Badoni ve ark., 2010).
Bu çalışmada *Celtis tournefortii* bitkisinin meyve ve yapraklarından elde edilen ekstraklarda toplam fenolik ve flavonoid madde miktarlarının belirlenmesi ve farklı yöntemler kullanarak antioksidan kapasitesinin incelenmesi amaçlanmıştır.

Materyal ve Metod

Bitki numunelerinin toplanması ve ekstrakt eldesi

Çalışmamızda kullandığımız *Celtis tournefortii* örnekleri Erzurum/Olur bölgesinden toplanmıştır. Toplanan bitki örnekleri fiziksel kirlerden arındırılmak amacıyla önce musluk suyu ile ardından destile su ile yıkandı. Numunelerin meyve ve yaprak kısımları ayrılarak gölgede kurutuldu. Kurutma işlemine numuneler sabit ağırlığa ulaşıncaya kadar devam edildi. Kurutulmuş numuneler öğütücü kullanılarak toz haline getirildi. Buradan alınan numune örnekleri üzerine 200 ml metanol ileve edilerek manyetik karıştırıcıda karıştırıldı. Elde edilen karışım süzüldü. Bu işlem 50 ml metanol ilave edilerek 3 kez tekrarlandı. Elde edilen karışımdaki metanol evaporatör yardımıyla uzaklaştırıldı. Elde edilen ekstraklardan 1000 µg/mL konsantrasyonda stok çözeltiler hazırlandı.

Toplam Fenolik ve Flavonoid Madde Tayini

Ekstrakların toplam fenolik madde tayini Folin-Ciocaltaeu metodu kullanılarak yapıldı (Slinkard ve Singleton 1977). Bunun için bir tüpe 1000 µg/mL stok çözeltiden 100 µL alınarak üzerine 100 µL Folin- Ciocaltaeu reaktifi ve 4.5 mL destile su ilave edildi. 3 dk bekletildikten sonra %2'lik Na_2CO_3 çözeltisinden 300 µL eklendi. Oda sıcaklığında 2 saat inkübe edilen karışım 760 nm'de absorbansı ölçüldü ve toplam fenolik madde miktarı standart grafik yardımıyla gallik aside eşdeğer olarak belirlendi (mg GAE/g). *C. tournefortii* meyve ve yaprak ekstraklarının toplam flavonoid madde miktarı alüminyum nitrat metodu kullanılarak belirlendi (Moreno et al. 2000). Stok çözeltiden 500 µL alınıp üzerine 1 M CH_3COOK çözeltisinden 100 µL ilave edilip 1 dk bekledikten sonra üzerine 100 µL %10'luk alüminyum nitrat eklendi. Toplam hacim 5 mL olacak şeklide etil alkol ilave edilip oda sıcaklığında 40 dk inkübe edildi. İnkübasyon süresi sonunda 415 nm'de absorbans değerleri belirlendi. Ekstraklarının toplam flavonoid madde miktarları standart kuersetin grafiği yardımıyla mg KE/g ekstrakt olarak hesaplandı.

DPPH• Serbest Radikal Giderme Aktivitesi Tayini

Ekstraların radikal giderme aktiviteleri Blois (1958) metodu kullanılarak belirlendi. Serbest radikal olarak 1,1-Difenil-2-pikrilhidrazil ve standart olarak 2,6-di-t-bütil-1-hidroksitoluen (BHT) kullanıldı. Ekstraktlardan 25, 50,

100, 150 ve 200 µg/mL konsantrasyonlarında hazırlanan çözeltilerden 500 µL ve DPPH çözeltisinden (0,1 mM) ise 2500 µL alınıp tüp içerisinde karıştırldı. Daha sonra oda sıcaklığında ve karanlıkta 30 dk inkübe edildikten sonra 517 nm'de absorbansları metanole karşı ölçüldü.

DPPH• radikali giderme aktivitesi (%) aşağıda verilen formül ile hesaplandı:

% İnhibisyon = $[(A_K - A_N) / A_K] \times 100$

A_K: Kontrol reaksiyonunun absorbansı, A_N: Örneğin absorbansı

Cu^{2+}-Cu^{+} Azaltma Kapasitesi (CUPRAC) Tayini

Ekstrakların Cu^{2+} indirgeme kapasitesini belirlemek için Apak ve ark., (2004) geliştirmiş oldukları metod kullanıldı. Öncelikle tüp içerisine 1'er mL $CuCl_2.2H_2O$ (10 mM), neokuprin (7,5 mM) ve NH_4CH_3COO (1 M) çözeltilerinden alındı. Üzerine 0.5 mL farklı konsantrasyonlarda hazırlanmış ekstrak çözeltisinden ve 0.5 mL saf su ilave edildi. Karışım 30 dk oda sıcaklığında bekletildikten sonra 450 nm'de absorbansları ölçüldü Standart olarak kullanılan BHT ve Troloks kullanıldı.

Fe^{3+}-Fe^{2+} İndirgeme Gücü Testi

Oyaizu (1986) metodu kullanılarak ekstraktın Fe^{3+} indirgeme gücü belirlendi. Bunun için farklı konsantrasyonlarda hazırlanmış ekstrak çözeltilerinden 0.5 ml alınıp üzerine 2.5 mL 0.2 M'lık fosfat tamponu (pH:6.6) ve 2.5 mL %1'lik $K_3Fe(CN)_6$ eklendi. Karışım 50 ºC'de 20 dk inkübe edildikten sonra %10'luk triklorasetik asit (TCA) ilave edilerek karıştırıldı. 2000 rpm'de 10 dk santrifüj sonunda tüplerden 2.5 mL başka bir tüpe alındı. Üzerine 2.5 mL saf su ve 0.5 mL $FeCl_3$ ilave edilerek 700 nm'de absorbans değeri belirlendi. Standart olarak BHT ve Troloks kullanıldı.

İstatiksel Analiz

Çalışmanın istatistiksel değerlendirilmesinde SPSS 22 V® istatistik paket programı kullanılmıştır. Başlangıçta tek yönlü kullanılmış, farklılıkların önemli olarak belirlendiği durumlarda ise çoklu karşılaştırma testlerden olan Duncan testi kullanılmıştır (Duggan ve ark., 2017). Çalışmada önemlilik düzeyi $P<0,05$ seviyesinde belirlenmiştir.

Bulgular ve Tartışma

Yüzyıllar boyunca varlığını sürdüren ve yerel halklar tarafından çeşitli adlarla bilinen doğal bitkiler, sürdürülebilir yaşam açısından büyük bir öneme sahiptir. Bu bitkiler, besleyici niteliklerinin yanı sıra tıbbi faydalar da sunmaktadır. Farklı yörelerde birçok değişik isimle anılan Dardağan bitkiside halk hekimliğinde kullanılan bitkilerden birisidir. Çalışmada materyal olarak kullandığımız *C. tournefortii* meyve ve yapraklarına ait Toplam fenolik ve flavonoid madde miktarları tablo 1'de verilmiştir.

Tablo 1. *C. tournefortii* meyve ve yaprak ekstraktlarının toplam fenolik ve flavonoid madde miktarları ve IC_{50} değeri

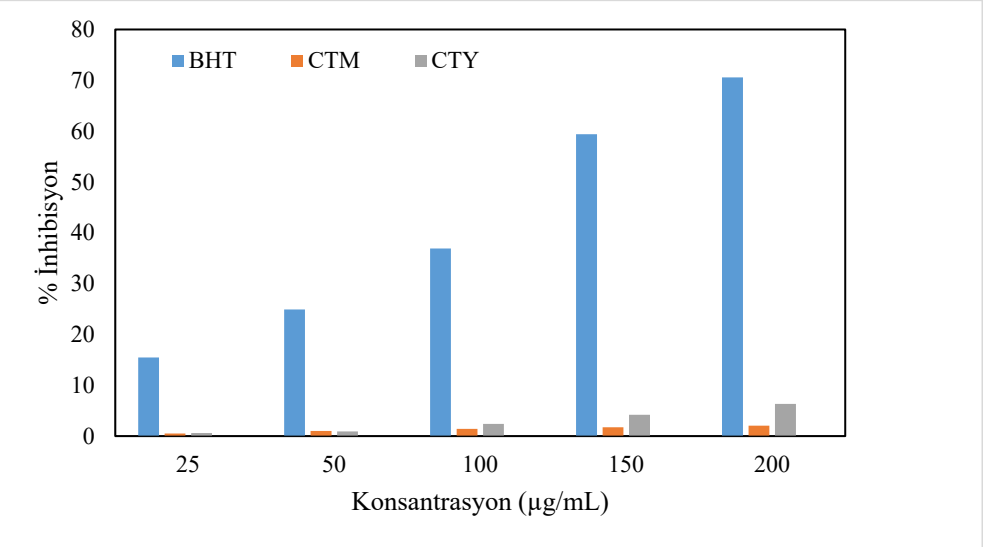
Örnekler	TPC (mg GAE/g)	TFC (mg KE/g)	IC_{50} (µg /mL)
CTM	2.0±0.10	11.71±0.14	6158.10±81.67
CTY	18.63±1.52	21.93±1.53	1567.87±41.27

CTM: *C. tournefortii* meyve ekstraktı, **CTY**: *C. tournefortii* yaprak ekstraktı, **TPC**: Toplam fenolik madde miktarı, **TFC**: Toplam flavonoid madde miktarı, **IC_{50}**: radikalinin %50'sinin inhibisyonunu sağlayan konsantrasyon.

Keser ve ark. 2017 yılında *C. tournefortii* meyveleriyle yaptıkları çalışmada metanol ekstraktında toplam fenolik madde miktarını 43.38±0.43 mg GAE/g ekstrakt, toplam flavonoid madde miktarını ise 1239.49±2.79 µg CAT/g ekstrakt olarak bildirmişlerdir. Başka bir çalışmada toplam fenolik miktarının 6.674±0.0012 mg of GAE/gr ve toplam flavonoid miktarının 1.932± 0.002 mg of KE/gr olduğu rapor edilmiştir (Yıldırım ve ark., 2017). Farklı dardağan türünde yapılan çalışmada toplam fenol miktarının olgun meyve su ekstraktında 0.27 g GAE/100 g, olgunlaşmamış meyve su ekstraktında ise 0.05 g GAE/100 g bulunduğu belirlenmiştir (Ota ve ark., 2017). Daha önce Safari ve ark. (2023) *C. Australis* genotipinde toplam fenolik madde miktarını 1176,73 mg GAE/100 g - 398,27 mg GAE/100 g aralığında olduğunu bildirmiştir. Aynı çalışmada toplam flavonoid madde miktarı 313,19 mg CA/100 g - 197,41 mg CA/100 g aralığında gözlendiği rapor edilmiştir. Mevcut çalışmadaki sonuçlar farklılıklar göstermektedir. *C. tournefortii*'nin toplam fenol ve flavonoid madde miktarlarındaki değişim genotipe, çevresel faktörlere, ekstraksiyon çözücüsünün türüne ve hasattaki olgunluk derecesine bağlı olabilir.

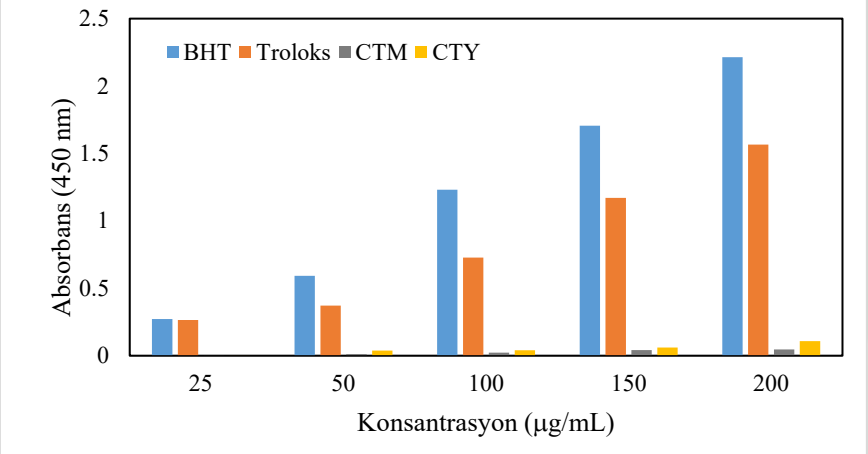
Mevcut çalışmada incelenen ekstrakların radikal giderme aktivitesi DPPH yöntemi ile değerlendirilmiştir. DPPH yöntemi kolay ve kısa sürede yapılıyor olması nedeniyle bitkilerde radikal yakalama aktivitesinin belirlenmesinde yaygın olarak kullanılanılır (Acet ve Özcan, 2023). Bu yöntem farklı *Celtis* türlerinde de yaygın olarak kullanılmıştır. *C. tournefortii* ile yapılan mevcut çalışmada DPPH inhibisyon değerleri meyvelerde %2.04±0.28,

yapraklarda ise %6.35±1.00 olarak hesaplandı (Şekil 2). Yaprakların DPPH giderme gücü meyvelerde yüksek olmasına rağmen genel olarak düşük bir aktivite gözlendi. Türk *C. tournefortii*'nin farklı kısımlarıyla yapılan benzer bir çalışmada DPPH radikal giderici aktivite %25,32 ± 1,03 ile %94,92 ± 0,11 arasında değişmiştir (Gecibesler, 2019). Yıldırım ve ark. (2017) *C. tournefortii*'nin metanol özütünde DPPH inhibisyonunu %52.46 olarak bildirmiştir. DPPH radikal giderme aktivitesini belirlemenin bir diğer yolu da IC_{50} değerlerinin belirlenmesidir. Bunun için farklı konsantrasyonlarda radikal giderme aktiviteleri belirlenip hesaplanan % inhibisyon değerleri ve konsantrasyonlar kullanılarak grafik çizildi ve grafik denklemlerinden yararlanılarak IC_{50} değerleri hesaplandı (tablo 1). IC_{50} değerleri *C. tournefortii*'nin yaprak ekstraktında daha düşük değerde çıkmıştır. Buda yaprak ekstraktının DPPH giderme kapasitesinin meyve ekstraktından fazla olduğunun göstergesidir. Çünkü IC_{50} değeri ile aktivite ters orantılıdır. Mevcut çalışmada ekstraktların her ikiside oldukça düşük radikal giderme aktivitesi göstermiştir.

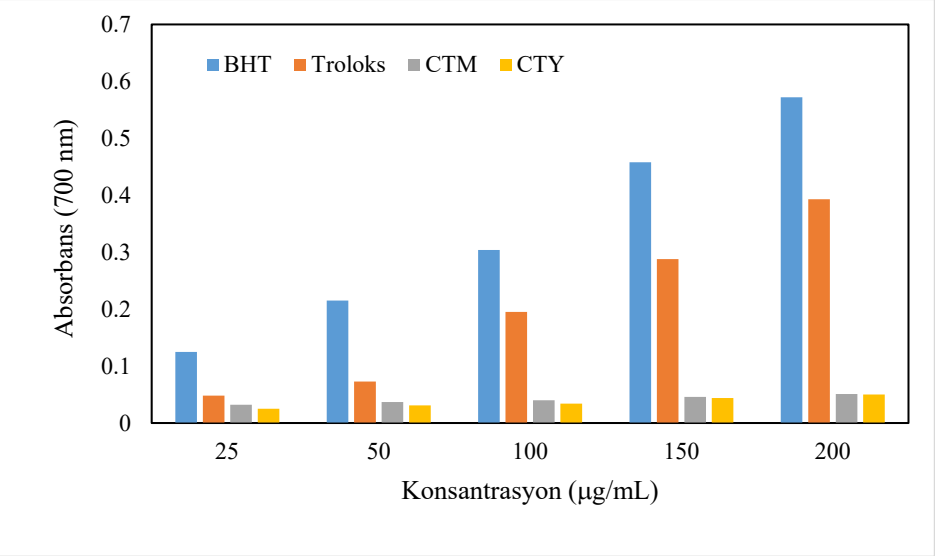


Şekil 2. *C. tournefortii* meyve ve yaprak ekstraktlarının ve BHT'nin konsantrasyona karşı % inhibisyon grafiği (**BHT:** 2,6-di-t-bütil-1-hidroksitoluen, **CTM:** *C. tournefortii* meyve ekstraktı, **CTY:** *C. tournefortii* yaprak ekstraktı)

C. tournefortii meyve ve yaprak ekstraktlarının indirgeme gücünün belirlenmesi için FRAP ve CUPRAC testleri uygulandı. Bunun için farklı konsantrasyonlarda ekstrak çözeltileri hazırlanıp testler ayrı ayrı uygulandı. Elde edilen absorbas değerleri ve konsantrasyonlar kullanılarak grafikler çizildi. Grafiklerde artan konsantrasyona paralel olarak absorbansın artması indirgemegücünün arttığını gösterir. Şekil 3'de görüldüğü gibi Cu^{2+}indirgeme kapasitesi oldukça düşük olmasına rağmen *C. tournefortii* yaprak ekstraktının indirgeme gücü meyve ekstraktından daha yüksektir. Benzer şekilde FRAP testi sonuçlarıda indirgeme gücünün düşük olduğunu göstermektedir (Şekil 4).



Şekil 3. *C. tournefortii* meyve ve yaprak ekstraktlarının ve standartların Cu^{2+} indirgeme gücünün karşılaştırılması (**BHT:** 2,6-di-t-bütil-1-hidroksitoluen, **CTM:** *C. tournefortii* meyve ekstraktı, **CTY:** *C. tournefortii* yaprak ekstraktı)



Şekil 4. *C. tournefortii* meyve ve yaprak ekstraktlarının ve standartların Fe^{3+} indirgeme gücünün karşılaştırılması (**BHT:** 2,6-di-t-bütil-1-hidroksitoluen, **CTM:** C. *tournefortii* meyve ekstraktı, **CTY:** *C. tournefortii* yaprak ekstraktı)

Troloks ile yapılan ölçüm sonuçları kullanılarak çizilen grafiğin eğimi ile numüneler için çizilen grafiklerin eğimleri oranlanarak CUPRAC ve FRAP aktiviteleri $TEAC_{CUPRAC}$ ve $TEAC_{FRAP}$ olarak ifade edilmiştir (tablo 2). Gıdalarda sentetik antioksidan olarak kullanılan BHT eşdeğer miktardaki Troloks'un yaklaşık 1.46 katı daha fazla CUPRAC antioksidan aktivitesi, 1.25 kat daha fazla FRAP aktivitesi göstermektedir Numunelerde ise eşdeğer miktardaki Troloksa en yakın değerin CUPRAC aktivitesinde 0.065 ile CTY'ye aitken FRAP aktivitesinde ise CTM numunesinde (0.2 kat) gözlenmiştir.

Tablo 2. Standart ve Bitki numuneleri için $TEAC_{CUPRAC}$ ve $TEAC_{FRAP}$ değerleri

	$TEAC_{CUPRAC}$	$TEAC_{FRAP}$
Troloks	1	1
BHT	1.46	1.25
CTM	0.039	0.2
CTY	0.065	0.05

***:** BHT: 2,6-di-t-bütil-1-hidroksitoluen, CTM: C. *tournefortii* meyve ekstraktı, CTY: *C. tournefortii* yaprak ekstraktı, $TEAC_{CUPRAC}$: Troloks eşdeğeri CUPRAC aktivitesi, $TEAC_{FRAP}$: Troloks eşdeğeri FRAP aktivitesi

Küresel ısınmanın etkisiyle dünyada ve ülkemizde yaşanabilecek su kıtlığı birçok sorunun ortaya çıkmasına neden olabilecektir. Bu bağlamada kuraklığa dayanan, tropikal iklimlerde yetişebilen bitkiler birçok ihtiyacı gidermek için kaynak olarak görülmektedir. Bu bitki türleri arasında *C. tournefortii* bitkiside yer almaktadır. Mevcut çalışmada *C. tournefortii* meyve ve yapraklarının metanol ekstraklarında toplam fenolik ve flavonoid madde miktarları belirlenmiş ve farklı yöntemler kullanılarak antioksidan kapasite değerlendirilmiştir. Ekstrakların antioksidan aktiviteleri düşük bulunmasına rağmen radikal giderme ve indirgeme gücünün var olduğu tespit edilmiştir. Elde edilen bulgular dardağan olarak isimlendirilen *C. tournefortii* bitkisinin fonksiyonel gıda bileşeni ve doğal antioksidan kaynağı olarak potansiyelini vurgulamakladır. Bitkinin ayrıca meyve, yaprak, tohum ile kabuklarının özellikle insan sağlığı ve halk hekimliğinde kullanılabilirliğinin belirlenebilmesi için farklı çözücüler ve yöntemlerinde kullanılacağı daha kapsamlı ve ileri araştırmalara ihtiyaç vardır.

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Bezelye (*Pisum sativum* L.) Çeşitlerinin Kalite Kriterlerine Ekim Zamanlarının Etkisi

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Özet

Bu çalışmada, Kahramanmaraş koşullarında bezelye yetişme sezonunda 5 farklı ekim zamanı uygulanarak Deren, Elena ve Irmak 01 bezelye çeşitlerinin kuru tane kalite özelliklerine ekim zamanlarının etkisi araştırılmıştır. Araştırmada bölünmüş parseller deneme deseninde kurularak ekim zamanları ana parsellere, çeşitler alt parsellere yerleştirilmiştir. Araştırmada bakla bağlama süresi, hasat süresi, hasat indeksi, bin tane ağırlığı, protein oranı, nişasta oranı, yağ oranı incelenmiştir. İncelenen özelliklerden bakla bağlama süresi, protein oranı, yağ oranı yönünden çeşitlere, ekim zamanlarına, çeşit x ekim zamanı interaksiyonları arasında istatiksel olarak önemli farklılıklar kaydedilmiştir. Nişasta oranı göre çeşitler arasındaki farklılıklar istatistiki olarak önemli olmuştur. Çeşitlere ve ekim zamanlarına göre bin tane ağırlığı istatistiksel önemli farklılıklar göstermiştir. Deren çeşidinin protein oranı yönünden diğer çeşitlerden daha yüksek değere sahip olduğu, geç ekimlerin protein oranını artırdığı, bin tane ağırlığının geç ekimlerde azaldığı, geç ve erken ekimlerde hasat indeksinin azaldığı kaydedilmiştir.

***Anahtar kelimeler**: Bezelye, çeşit, ekim zamanları, kalite kriterleri, hasat indeksi.*

Effect of Planting Times on Quality Criteria of Pea (*Pisum sativum* L.) Varieties

Abstract

In this study, the effects of planting times on dry grain quality traits of Deren, Elena and Irmak 01 pea varieties were investigated by applying 5 different planting times in the pea growing season in Kahramanmaras conditions. In the trials, split plots were established in the experimental design and planting times were placed in main plots and varieties were placed in sub-plots. In the research, pod setting time, harvest period, harvest index, thousand grain weight, protein content, starch content and oil content were examined. Statistically significant differences were recorded planting times, and variety x planting time interactions in terms of the examined traits, such as pod setting time, protein content, and oil content of the varieties. The differences between the varieties according to starch content were statistically significant. Thousand grain weight showed statistically significant differences according to varieties and planting times. It was recorded that the Deren variety had a higher value than the other varieties in terms of protein content, late plantings increased the protein content, thousand grain weight decreased in late plantings, and harvest index decreased in late and early plantings.

***Keyword:** Peas, variety, planting times, quality criteria, harvest index.*

Giriş

Dünyanın her yerinde yetiştirilen ve baklagiller grubunda yer alan bezelye, son derece besleyicidir ve yüksek oranda sindirilebilir protein, karbonhidrat, mineral ve vitamin içermesi konserve olarak kullanılma özelliğinden dolayı, mutfaklarda hızlı şekilde yemeğe dönüştürülecek önemli bir gıda ürünüdür (Sharma, 2010). Bezelye (*Pisum sativum*) önemli bir besin bileşeni kaynağıdır ve protein, nişasta ve lif açısından zengindir. Bezelye proteini, düşük alerjenitesi, yüksek protein içeriği, bulunabilirliği, uygun fiyatlı olması ve sürdürülebilir bir üründen elde edilmesi nedeniyle küresel endüstride yüksek kaliteli bir protein ve işlevsel bir bileşen olarak kabul edilir. Ayrıca glütensiz ve genetiği üzerinde oynanmamış olması, bezelye proteini tahılların, unlu mamullerin, et, süt ürünlerinin, içeceklerin, besleyici ve teknolojik özelliklerini iyileştirmek için mükemmel bir bileşen olarak kullanılacak bir gıda ürünüdür (Shanthakumar ve ark. 2022). Son on yılda, bitki bazlı proteinlere olan talep artmaktadır. Bitkisel bazlı proteinler obezite, yüksek tansiyon ve diyabet riskini azaltmaktadır. Çoğu bitki bazlı protein için en az bir temel amino asit yoktur, ancak bezelye proteini lizin açısından zengindir ve bu da sağlıklı bir bağışıklık sistemini korumaya yardımcı olmaktadır (Huntrakul ve ark. 2020). Bezelye tarımında, su, kimyasallar ve düşük besin gereksinimine ihtiyaç duyulması yanı sıra atmosferik nitrojeni simbiyotik olarak sabitleme yeteneği nedeniyle sürdürülebilir tarım sistemlerinde büyük avantajlara sahiptir (MunierJolain and Carrouee 2003; Smytkiewicz ve ark. 2021). Bezelye yetiştiriciliğinde potansiyel verimi elde etmek için optimum ekim tarihi ve uygun çeşit gibi tarımsal uygulamalar öncelikli çalışılması gereken konulardır. Çeşitlerin uygun zamanda ekilmemesi verimde azalmaya ve kalitede düşmeye neden olmaktadır. Ekim zamanları bitkinin büyümesi ve

verimin üzerinde belirgin etkiye sahip olduğu gibi ekonomik kayıpta oluşturmaktadır (Ahmed ve ark., 2020). Ekim zamanlarının doğru tespiti bitkinin ekolojiyi de çok iyi kullanmasına ve çevre sağlığında katkı sağlamış olacaktır (Vange ve Obi, 2006). Akdeniz iklimine sahip bölgelerde bezelye ekimi Kasım ayından Mart ayına kadar sürebilir. Geç ekilen çeşitlerde çiçeklenme sırasında sıcaklık stresi maruz kalabilmektedir. Bu durum küçük tohumların oluşmasına ve yüksek protein birikimi neden olabilmektedir. Bezelye yetiştiriciliğinde verim kayıpları, çeşide, ekim zamanına, iklim koşullarına ve lokasyona bağlı olarak %30 ile %60 arasında değişmektedir (McDonald ve Peck, 2009). Uygun ekim tarihini, erken don hasarının olumsuz etkilerini azaltmaya ve bitkileri bakla oluşumu ve tane doldurma dönemleri gibi kritik aşamalarda oluşabilecek yüksek sıcaklıklardan zararını azalmaya yardımcı olabilir (Sümer 2024). Değişen iklim koşulları bölgelere uygun optimum ekim tarihin seçiminin araştırmalarla ortaya konmasını gerektirmektedir. Bu nedenle Kahramanmaraş koşullarında üç bezeyle çeşidine beş farklı ekim zamanı uygulanarak, uygun ekim zamanı belirlemeye çalışılmıştır.

Materyal ve Metot

Denemede materyal olarak Elena, Deren ve Irmak 01 bezelye çeşitleri kullanılarak, Kahramanmaraş koşularında Kasım-2022, Aralık-2022, Ocak-2023, Şubat-2023 ve Mart-2023 olmak üzere beş farklı ekim zamanı uygulanmıştır. Bölünmüş deneme deseninde kurulan denemede ekim zamanları ana parsellere, çeşitler alt parsellere yerleştirilmiştir. Üç tekerrürlü kurulan denemede parsel uzunluğu 5 m sıra arsı 50 cm, sıra üzeri 8 cm olacak şekilde 4 sıra olarak elle ekilmiştir. Ekim sırasında dekara 13 kg olacak şekilde (18-46 DAP) taban gübresi uygulanmıştır. Azotlu gübresi üst gübre olarak bitki boyu 10-15 cm iken net 8 kg da^{-1} azot düşecek verilmiştir. Bezelye ekimleri hava koşulları ve toprağın nem durumu dikkate alınarak her ayın 15'den sonra ekimler yapılmıştır. Kasım, Aralık, Ocak ekimlerinde toprak nemi yeterli olurken, Şubat ve Mart ekimlerinde çimlenmeyi sağlamak için sulama yapılmıştır. Bitkinin gelişme sürecinde toprak nemi ve bitki durumu gözlenerek Nisan ve Mayıs aylarında damla sulama uygulanmıştır. Nisan ayının sonunda Mildiyö hastalığına karşı (%64 mancozeb + %8 metalaxy) 40 g da-1 ve 60 g da-1 bakırsülfat çözeltisi sırt pompası ile uygulanmıştır. Mayıs ayında da beyaz sinek için (25 ml $da^{-1)}$ 141 g lt^{-1} Thiamethoxam + 106 g lt^{-1} lambda cyhalothrin kullanılarak mücadele edilmiştir. Hasat, yaprakların ve baklalarının kuruduğu, ayrıca baklaları sallayınca tanelerin baklalar içinde hareket seslerinin hissedilmesiyle geçekleştirilmiştir. Hasat sonrasında elde edilen kuru tane örnekleri değirmende öğütülerek un haline getirilmiştir. Un örnekleri Samsun On dokuz Mayıs Üniversitesi laboratuvarında FOSS 6500 NIR sistem cihazında WINISI paket programları kullanılarak protein, nişasta, yağ oranı belirlenmiştir. Araştırmada tanenin bin tane ağırlığı, hasat indeksi, hasat zamanı, protein oranı, nişasta oranı, yağ oranı incelenmiştir. Denemenin yürütüldüğü alanının toprağı hafif alkali ve tuzlu, kireçli, potasyum ve fosfor yeterli düzeyde, organik maddece orta, killi bünyeye sahip yapıdadır. Denemenin yürütüldüğü bölgeye ait bazı iklim verileri çizelge 1. verilmiştir.

Çizelge 1. Deneme yürütüldüğü Kahramanmaraş iline ait bazı iklim verileri

Aylar	Yağış (mm)	Nem (%)	Sıcaklık min.(°C)	Sıcaklık mak.(°C)	Sıcaklık ort.(°C)
Kasım 2022	65,0	77,1	5,0	27,4	13,0
Aralık 2022	34,8	89,1	3,6	19,6	8,8
Ocak 2023	57,4	82,5	-1,0	17,4	5,6
Şubat 2023	67,0	65,5	-6,7	26,0	4,8
Mart 2023	138,4	75,3	1,0	27,3	12,1
Nisan 2023	66,6	73,9	4,3	30,4	14,4
Mayıs 2023	30,0	57,9	9,8	35,5	19,9
Haziran 2023	0,4	50,8	14,6	39,6	25,8

Anonim (2024).

Çizelge 1'den denemenin yürütüldüğü bölgeye en az yağışın Haziran ayında düştüğü, onu Mayıs ayı ikinci sırada ve Aralık ayı üçüncü sırada izlediği ve en yüksek yağışın Mart ayında düştüğü görülmektedir. Minimum sıcaklığın Ocak ve Şubat ayında sıfırın altında seyrettiği, maksimum sıcaklığın Nisan ayı dahil olmak üzere 30 °C'nin üstünde olduğu kaydedilmiştir.

Araştırma sonunda elde edilen veriler JUMP paket programı kullanılarak, varyans analizi bölünmüş parseller deneme desenine göre yapılmıştır. Varyans analizinde elde edilen ortalamalarda çoklu Duncan karşılaştırma testi uygulanmıştır.

Bulgular ve Tartışma

Kahramanmaraş merkezde bezelye yetişme sezonu dikkate alınarak Elena, Deren ve Irmak 01 bezelye çeşitleri beş farklı ekim zamanında ekilerek yetiştirilen bezelye bitkisinin hasat süresi (gün), hasat indeksi (%), bakla bağlama

süresi (gün), bin tane ağırlığı (g), protein oranı (%), nişasta oranı (%) ve yağ oranı (%) özellikleri incelenmiştir. İncelenen özelliklere ait sonuçlar ve laboratuvar analizleri alt başlıklar halinde sıralanmıştır.

Hasat Süresi (gün)

Kahramanmaraş koşullarında farklı bezelye çeşitleri ve ekim zamanları uygulanarak yürütülen çalışmada hasat indeksi yönünden çeşitler, ekim zamanları ve çeşit x ekim zamanı interaksiyonunun istatistiksel olarak önemli olduğu, araştırmada elde edilen ortalamalar ve grupları Çizelge 2'de verilmiştir.

Çizelge 2. Farklı ekim zamanı uygulanan bezelye çeşitlerinin hasat sürelerine ait ortalamalar ve Duncan testine göre oluşan grupları

Ekim zamanları	Hasat Süresi (gün)			
	Elena	Deren	Irmak 01	Ort.
Kasım	196,00 a	195,00 b	195,00 b	195,33 a
Aralık	176,00 d	175,00 e	177,00 c	176,00 b
Ocak	141,00 g	141,00 g	142,00 f	141,33 c
Şubat	111,00 ı	112,00 h	112,00 h	111,66 d
Mart	90,00 k	91,00 j	90,00 k	90,33 e
Ortalama	142,80 b	142.80 b	143,20 a	

Yürütülen araştırmada kullanılan çeşitler ve ekim yapılan tarihlere göre bitkilerin hasat olgunluğuna gelme süreleri değişiklik göstermiştir. Kullanılan çeşitler arasında Irmak 01 çeşidi 143.20 gün ile hasat olgunluğuna gelirken, Elena ve Deren çeşidi 142.80 gün ortalaması ile hasat olgunluğuna gelmiştir. Ekim zamanlarına göre bitkilerin hasat süreleri önemli derecede farklılık göstermiş olup, en uzun hasat süresi 195,33 gün ile Kasım ayında yapılan ekimlerde görülmüştür. Aralık ayında yapılan ekimler ortalama 176,00 günde hasat olgunluğuna gelirken onu üçüncü sırada 141,33 gün ile Ocak ayında yapılan ekimler izlemiştir. Şubat ayında yapılan ekimler 111,66 gün ortalaması ile hasat olgunluğuna gelirken, en kısa hasat süresi 90,33 gün ile Mart ayında yapılan ekimlerde görülmüştür. Çeşit x ekim zamanları interaksiyonlarına göre bitkilerin hasat süresi önemli farklılıklar göstermiştir. En uzun hasat süresi 196,00 gün ile Elena çeşidinin Kasım ayı ekimlerinde elde edilirken, Deren ve Irmak çeşidinin Kasım ayında yapılan ekimleri 195,00 gün ile ikinci sırada yer almıştır. En düşük hasat süresi ise 90,00 gün ile Elena ve Irmak 01 çeşitlerinin Mart ayı ekimlerinde görülürken, Deren çeşidinin Mart ayında yapılan ekimi 91,00 gün ortalamada hasat olgunluğuna gelmiştir. Çeşit x ekim zamanları interaksiyonlarında, aynı ekim zamanlarında kullanılan çeşitler arasında ciddi farklılıklar bulunmamaktadır fakat aynı çeşitlerin çeşitlerin farklı ekim zamanlarında ekilmesi hasat süresini önemli derecede etkilemektedir.

Hasat İndeksi (%)

Farklı ekim zamanlarının Kahramanmaraş koşullarında farklı bezelye çeşitlerine uygulanarak yürütülen çalışmada hasat indeksi yönünden ekim zamanları ve çeşit x ekim zamanı interaksiyonunun istatistksel olarak (0.01) önemli olduğu, araştırmada elde edilen ortalamalar ve grupları Çizelge 3'te verilmiştir.

Çizelge 3. Farklı ekim zamanı uygulanan bezelye çeşitlerinin hasat indeksi ait ortalamalar ve Duncan testine göre oluşan grupları

Ekim zamanları	Hasat İndeksi (%)			
	Elena	Deren	Irmak 01	Ort.
Kasım	46,02 bcdef	41,15 gh	45,29 cdef	44,15 c
Aralık	46,40 abcde	48,36 ab	45,03 def	44,60 b
Ocak	48,60 ab	47,78 abc	48,64 a	48,34 a
Şubat	47,88 ab	41,81 gh	47,35 abcd	45,68 b
Mart	44,72 ef	40,83 h	43,50 fg	43,02 c
Ortalama	46,72	43,99	45,96	

Yapılan araştırmada kullanılan bezelye çeşitleri, istatistiksel olarak önemli farklılıklar oluşturmamıştır. Elena, Irmak 01, Deren çeşitleri sırayla %46.76, %45,96, %43,99 hasat indeksi diğerlerine sahip olmuştur. Ekim zamanlarının hasat indeksleri ortalamaları, istatistiksel olarak önemli bulunmamış olup, %44,15-45,68 arasında değişen değerler oluşturmuşlardır. En yüksek % 48.34 hasat indeksi ile Ocak ayı ekiminde kaydedilmiştir. Aralık ve Şubat ayı ekimleri istatistiki olarak aynı grupta yer alarak diğer ekimlerden önemli farklılıklar göstermiştir. En düşük hasat indeksi Mart ayı ekiminden elde edildiği ve Kasım ayı ekimiyle de aynı istatistiki grupta yer alarak diğer ekim zamanları arasında önemli farklılık oluşturduğu kaydedilmiştir. Çeşit x ekim zamanları interaksiyonlarının hasat indeksleri incelendiğinde, en yüksek hasat indeksleri %48,64 ile Irmak 01 çeşidinin Ocak ayı, %48.60 ile Elena Ocak ayı, %47.35 hasat indeksi ile Irmak 01 çeşidinin Şubat ayı ekimlerinden, %48,36 ile

Deren çeşidinin Aralık ayı ekimlerinden, %47,88 ile Elena çeşidinin Şubat ayı ekimlerinden ve %47,78 ile Deren çeşidinin Ocak ayı, %46.40 ile Elena Aralık ayı ekimlerinden elde edildiği ve aralarında istatistiki olarak fark bulunmadığı tespit edilmiştir. En düşük hasat indekslerinin, %40.83 ile Deren çeşidinin Mart ekiminden elde edildiği ve Deren çeşidinin Şubat ayı ekimi arasında fark oluşturmadığı kaydedilmiştir (Çizelge 6.) Daha önce yapılan çalışmalarda bezelyede hasat indeksini Kılıç (2017), Giresun koşullarında yerel bezelye çeşitlerinin %53-73, Özaktan ve ark. (2022), Kayseri koşullarında farklı sulama faktörlerinde %38-56 arasında değişim gösterdiğini tespit edilmiştir. Önceki yapılan çalışmalardan da anlaşıldığı gibi hasat indeksinin çeşit özelliğinin yanı sıra çevresel etkinin katkısını daha yüksek olduğu görülmektedir.

Bakla Bağlama Süresi (gün)

Bezelye çeşitlerine farklı ekim zamanları uygulanarak yürütülen çalışmada bağla bağlama süresi yönünden ekim zamanları (0.05), çeşit, çeşit x ekim zamanı interaksiyonunun istatistksel olarak (0.01) önemli olduğu, araştırmada elde edilen ortalamalar ve grupları Çizelge 4'te verilmiştir.

Çizelge 4. Farklı ekim zamanı uygulanan bezelye çeşitlerinin bakla bağlama sürelerine ait ortalamalar ve Duncan testine göre oluşan grupları.

Ekim zamanları	Bakla Bağlama Süresi (gün)			
	Elena	Deren	Irmak 01	Ort.
Kasım	143,33 b	134,33 c	150,66 a	142,77 a
Aralık	128,66 d	118,00 e	131,00 d	125,88 b
Ocak	95,66 f	90,33 g	97,00 f	94,33 c
Şubat	82,66 h	77,33 ı	84,00 h	81,33 d
Mart	73,33 jk	71,33 k	74,33 j	73,00 e
Ortalama	104,73 b	98,26 c	107,40 a	

Araştırmada kullanılan bezelye çeşitleri, bakla bağlama süreleri yönünden istatistiksel olarak farklılık oluşturmuştur. En geç bakla bağlama süresi ortalaması 107,40 gün ile Irmak 01 çeşidinde görülürken, onu ikinci sırada 104,73 gün ile Elena çeşidi izlemiştir. En erken bakla bağlama süresi ise 98,26 gün ile Deren çeşidinde kaydedilmiş olup, tüm bezelye çeşitleri farklı istatistiksel grupta yer almıştır. Ekim yapılan tarihler incelendiğinde, Kasım ayından Mart ayına doğru bakla bağlama süresinin giderek kısaldığı görülmektedir. En geç bakla bağlama süresi 142,77 gün ortalama ile Kasım ayında yapılan ekimlerde görülürken onu sırasıyla 125,88 gün ile Aralık, 94,33 gün ile Ocak, 81,33 gün ile Şubat ayında yapılan ekimler izlemiştir. En erken bakla bağlama süresi ortalaması, 73,00 gün ile Mart ayında yapılan ekimlerde görülürken, tüm ekim zamanları birbirinden farklı istatistiksel grupta yer almıştır. Çeşit x ekim zamanları interaksiyonlarına göre bakla bağlama süreleri önemli farklılıklar göstermiştir. Irmak 01 çeşidinin Kasım ayında yapılan ekimi 150,66 gün olurken, onu 143,33 gün ile Elena çeşidinin Kasım ayı ekimi ve 134,33 gün ile Deren çeşidinin Kasım ayı ekimi izlediği ve farklı istatistiki grupları oluşturdukları belirlenmiştir. En erken bakla bağlama süresi 71,33 gün ile Deren çeşidinin Mart ay ekiminde görüldüğü ve onu 73,33 ile gün izleyen Elena çeşidinin Mart ayı ekimi hariç diğer çeşit x ekim zamanı interaksiyonlarından istatistiksel olarak önemli farklılıklar oluşturduğu akydedilmiştir. Diğer çeşit x ekim zamanı interaksiyonlarının bakla bağlama süreleri 74,33-131,00 gün arasında değişiklik göstermiştir. (Çizelge 4.). Luthra ve ark. (2024), Hindistan'ın Prayagraj bölgesinde 25 bezelye çeşidiyle yapılan çalışmada %50 bakla bağlama süresinin 33,92-68,23 gün arasında değiştiğini kaydetmişlerdir. Bezelye bitkisi ılıman iklim bitkisi olduğu için soğuk ve sıcağa hassasiyeti gelişme evrelerindeki tepkisiyle göstermektedir.

Bin Tane Ağırlığı (g)

Kahramanmaraş koşullarında farklı bezelye çeşitleri ve ekim zamanları uygulanarak yürütülen çalışmada bin tane ağırlığı yönünden çeşitler ve ekim zamanları istatistiksel olarak 0.01 düzeyinde önemli olduğu, araştırmada elde edilen ortalamalar ve grupları Çizelge 5'de verilmiştir.

Çizelge 5. Farklı ekim zamanı uygulanan bezelye çeşitlerinin bin tane ağırlığına ait ortalamalar ve Duncan testine göre oluşan grupları

Ekim zamanları	Bin Tane Ağırlığı (g)			
	Elena	Deren	Irmak 01	Ort.
Kasım	145,43	180,59	228,00	184,67 ab
Aralık	163,32	182,70	234,60	193,54 a
Ocak	175,49	177,34	236,75	196,52 a
Şubat	161,33	168,00	206,67	178,67 b
Mart	134,48	152,85	186,36	157,90 c
Ortalama	156,01 c	172,30 b	218,48 a	

Araştırmada denemeye alınan bezelye çeşitleri, bin tane ağırlıklarına göre istatiksel üç grup oluşturmuştur. Bin tane ağırlığında sırasıyla en yüksek değer 218,48 g ile Irmak 01 çeşidinde, onu 172,30 g ile Deren çeşidinin ve en düşük 156,01 g ile Elena çeşidinin izlediği görülmüştür. Ekim zamanlarına göre bin tane ağırlığı istatistiksel olarak üç grup ve bir geçiş grubuna sahip olmuştur. Bin tane ağırlığında en yüksek değer 196.52 g olarak Ocak ayı ekiminde kaydedildiği, onu ikinci sırada 193.54 g ile Aralık ekiminin, üçüncü sırada 184.67 g ile kasım ekimin izlediği ve aralarında istatistiki farklılık oluşturmadığı görülmüştür. Mart ayı ekimi 152.90 g ile en düşük bin tane ağırlığına sahip diğer ekim zamanlarından önemli farklılıklar oluşturduğu kaydedilmiştir. Şubat ayı ekimi bin tane ağırlığında ikinci en düşük bin tane ağırlığına sahip olarak farklı grupta yer almıştır. Çeşit x ekim zamanı interaksiyonları yönünden bin tane ağırlıkları arasında istatiksel farklılıklar görülmemiştir. Irmak 01 çeşidi Ocak ayı ekiminde 236,75 g ile en yüksek bin tane ağırlığına sahip olduğu, Elena çeşidi Mart ayı ekiminde 134,48 g ile en düşük bin tane ağırlığı gösterdiği kaydedilmiştir. Bin tane ağırlığı değerleri diğer interaksiyonlarında 145,43-234,60 g arasında değiştiği belirlenmiştir (Çizelge 5.). Bezelye ile daha önce yapılan çalışmalarda bin tane ağırlığı değerlerinin Ceyhan ve ark. (2005), Konya koşullarında 101-236 g, Toğaç ve ark. (2006), Van koşullarında 141,4-143,6 g, Timuroğlu ve ark. (2004), Ankara koşullarında yemlik bezelye hatlarında ilk sene 125-228 g arasında, ikinci sene 102-165 g arasında, Karayel (2006), Samsun ekolojik 103-364 g arasında olduğunu, Khan ve ark. (2013), Pakistanda 82,33-171 g, Kılıç (2017), Giresun yöresinde 128,39-2443,82 g, Gali ve ark. (2019), 171-225 g, Özaktan ve ark. (2022), Kayseri koşullarında 144,7-163,2 g arasında değiştiğini kaydetmişlerdir. Daha önceki araştırmalardan, bin tane ağırlığının çeşit karakteri yanı sıra iklim, çevresel faktörler ve uygulama faktörlerinden etkilendiği anlaşılmaktadır. Çalışmada elde edilen araştırma sonuçlar çeşit ve çevre etkisini açıklamaktadır. En düşük bin tane ağırlığının Mart ayı ekiminde elde edilmesi, sıcaklıkların artmasıyla bitkinin fizyolojik olumunun kısalması bin tanenin ağırlığının düşmesine neden olmuştur.

Protein Oranı (%)

Kahramanmaraş koşullarında farklı bezelye çeşitleri ve ekim zamanları uygulanarak yürütülen çalışmada protein oranı yönünden çeşitler, ekim zamanları ve çeşit x ekim zamanı interaksiyonunun istatistiksel olarak önemli olduğu, araştırmada elde edilen ortalamalar ve grupları Çizelge 6'da verilmiştir.

Çizelge 6. Farklı ekim zamanı uygulanan bezelye çeşitlerinin protein oranına ait ortalamalar ve Duncan testine göre oluşan grupları

Ekim zamanları	Protein Oranı (%)			
	Elena	Deren	Irmak 01	Ort.
Kasım	24,30 e	26,46 bcd	22,89 f	24,55 c
Aralık	24,45 e	26,15 cd	24,46 e	25,02 c
Ocak	24,55 e	27,54 ab	25,41 de	25,83 b
Şubat	24,70 e	27,96 a	26,12 cd	26,26 ab
Mart	26,15 cd	27,43 ab	27,08 abc	26,88 a
Ortalama	24,83 b	27,11 a	25,19 b	

Yürütülen araştırmada, protein oranı yönünden kullanılan bezelye çeşitleri arasında istatistiki olarak 0.01 önem seviyesinde farklılıklar bulunmuştur. Çeşitler istatistiki olarak iki grup oluşturmuştur. En yüksek %27.24 ile protein oranı ile Deren çeşidi ilk sırayı almıştır. Elena ve Irmak 01 çeşitlerin sırasıyla %24, 25.19 protein oranıyla ikinci istatiksel grupta yer almıştır. Protein oranı ortalamaları incelendiğinde ekim zamanlarına göre, istatistiksel olarak üç ana grup ve bir geçiş grubu oluşturmuştur. En yüksek protein oranı, %26,88 ile Mart ayında yapılan ekimlerde görülürken, onu ikinci sırada %26,26 ile Şubat ayında yapılan ekimler izlemiştir ve aralarında istatistiksel olarak fark bulunmamaktadır. En düşük protein oranı, %24,55 ve %24,80 protein oranları ile Kasım ve Aralık ayında yapılan ekimlerde belirlenmiş olup, aynı istatistik grupta yer almışlardır. Çeşit x ekim zamanı interaksiyonlarında protein oranları %22,89-28,20 arasında değişmektedir. En yüksek protein oranı, %28,20 ile Deren çeşidinin Ocak ayında yapılan ekiminde görülmüş olup, Deren çeşidinin Şubat ve Mart ayı ekimleri, Irmak çeşidinin Mart ayı ekimi ile arasında istatistiksel olarak fark görülmemiştir. Çeşit x ekim zamanı interaksiyonlarında en düşük protein oranı %22,89 ile Irmak 01 çeşidinin Kasım ayında yapılan ekiminde belirlenmiştir ve Elena çeşidinin Aralık ayında yapılan ekimi ile arasında istatistiksel olarak fark olmadığı görülmektedir (Çizelge 6.).

Bezelyeyle ilgili daha önce yapılan çalışmalarda protein oranının Timuroğlu ve ark. (2004), Ankara koşullarında yemlik bezelye hatlarında birinci yıl %16-19, ertesi yıl %17-23, Karayel (2006), Samsun koşullarında %16,3-23,6, Kılıç (2017), Giresun bölgesinde %19,86-28,12, Gali ve ark. (2019), %22,8-25,4, Özaktan ve ark. (2022), Kayseri koşullarında sulamanın etkisini araştırdıkları çalışmada, %32,45-34,59, Volobueva ve ark (2024), Rusya-Oryol bölgesinde %20-24,9 arasında değiştiğini belirtmişlerdir. Sümer (2024), Aydın koşullarında Deren ve Irmak 01 çeşitlerini kapsayan beş bezelye çeşidinin 15 Kasım, 30 Kasım, 15 Aralık ekimlerinde sırasıyla protein oranının %27,75, %26,55 ve %26,67 olduğunu ve ortalama protein oranının %25,16-28,48 arasında değişim gösterdiğini

tespit etmiştir. Yürütülen çalışmada protein oranlarının ekim zamanlarının gecikmesiyle artış gösterdiği ve protein oranı üzerindeki genetik faktörlerin etkisi olmakla birlikte çevresel faktörlerden de etkilendiğini göstermektedir.

Nişasta Oranı (%)

Farklı bezelye çeşitleri ve ekim zamanları uygulanarak Kahramanmaraş koşullarında yürütülen çalışmada nişasta oranı yönünden çeşitler istatistiksel olarak 0.05 önem düzeyinde önemli olduğu tespit edilmiştir. Araştırmada elde edilen ortalamalar ve grupları Çizelge 3'de verilmiştir

Çizelge 7. Farklı ekim zamanı uygulanan bezelye çeşitlerinin nişasta oranına ait ortalamalar ve Duncan testine göre oluşan grupları

Ekim zamanları	Nişasta Oranı (%)			
	Elena	Deren	Irmak 01	Ort.
Kasım	47,45	46,28	50,84	48,19
Aralık	48,45	47,66	49,60	48,57
Ocak	48,66	46,82	49,64	48,37
Şubat	49,20	46,56	48,41	48,06
Mart	47,35	47,74	47,33	47,47
Ortalama	48,22 ab	47,01 b	49,16 a	

Çalışmada kullanılan bezelye çeşitleri, nişasta oranı bakımından önemli farklılıklar göstermiştir. En yüksek nişasta oranı %49,16 ile Irmak 01 çeşidinde görülürken, %48,22 nişasta oranı ile ikinci sırada bulunan Elena çeşidi ile aynı istatistiksel grupta yer almıştır ve aralarında istatistiksel bir fark oluşmamıştır. En düşük nişasta oranı ise %47,01 ile Deren çeşidinde belirlenmiş olup, diğer iki çeşitten farklı bir istatistiksel grupta yer almıştır. Ekim zamanları arasında nişasta oranı özelliğinde önemli bir fark bulunmamış olup, en yüksek nişasta oranı %41,91 ile Aralık ayında yapılan ekimlerde, en düşük nişasta oranı ise %40,81 ile Mart ayında yapılan ekimlerde kaydedilmiştir. Çeşit x ekim zamanları interaksiyonlarında en yüksek nişasta oranı %50,84 ile Irmak 01 çeşidinin Kasım ayı ekiminden elde edilirken, en düşük nişasta oranı %26,28 ile Deren çeşidinin Kasım ayı ekiminde belirlenmiştir (Çizelge 7.).

Gali ve ark. (2019), 135 bezelye materyalinde nişasta oranını %38,7-52,2, Volobuevaa ve ark (2024), Rusya-Oryol yöresinde biyolojik ürünler ile büyüme düzenleyicilerinin uyguladığı iki bezelye çeşidine nişasta formunda oluşan karbonhidratların %24-49 arasında değiştiğini kaydetmişlerdir. Nişasta oranı genetik faktörlerin etkisi yanı sıra çevresel faktörlerden de etkilenebilmektedir.

Yağ Oranı (%)

Elene, Deren ve Irmak 01 bezelye çeşitleri Kahramanmaraş koşullarında beş farklı zamanda ekilerek yetiştirilmesi sonucunda yağ oranı yönünden çeşitler, ekim zamanları ve çeşit x ekim zamanı interaksiyonu 0.01 önem düzeyinde istatistiksel olarak önemli bulunduğu kaydedilmiştir. Araştırma sonucunda elde edilen ortalamalar ve grupları Çizelge 8'de verilmiştir.

Çizelge 8. Farklı ekim zamanı uygulanan bezelye çeşitlerinin yağ oranına ait ortalamalar ve Duncan testine göre oluşan grupları.

Ekim zamanları	Yağ Oranı (%)			
	Elena	Deren	Irmak 01	Ort.
Kasım	1,76 c	2,40 a	1,54 ef	1,90 ab
Aralık	1,85 c	2,39 a	1,63 de	1,95 a
Ocak	1,80 c	2,20 b	1,62 de	1,87 b
Şubat	1,76 c	2,18 b	1,42 fg	1,79 c
Mart	1,75 cd	2,14 b	1,40 g	1.76 c
Ortalama	1,78 b	2,26 a	1,52 c	

Yürütülen araştırmada kullanılan bezelye çeşitleri, yağ oranları bakımından incelendiğinde, üç farklı istatistiksel grup oluştuğu görülmektedir. Deren çeşidi, %2,26 yağ oranıyla en fazla yağ oranına sahip çeşit olurken, onu ikinci sırada %1,78 yağ oranı ile Elena çeşidi izlemiştir. Denemede kullanılan çeşitler arasında en düşük yağ oranına sahip çeşit, %1,52 ile Irmak 01 çeşidi olmuştur. Ekim zamanları ortalamaları, istatistiksel olarak üç ana grup ve bir geçiş grubu oluşturmuştur. En yüksek yağ oranı, %1,95 ile Aralık ayında yapılan ekimlerden elde edilirken, Kasım ayında yapılan ekimlerden elde edilen %1,90 yağ oranı ikinci sıradadır ve bu iki ekim zamanı arasında istatistiksel olarak fark bulunmamaktadır. En düşük yağ oranına sahip ekim zamanları, %1,79 ile Mart ayı ve %1,76 ile Şubat ayı ekimlerinden elde edilmiştir. Bu iki ekim zamanı istatistiksel olarak aynı grupta yer aldığı için, aralarında istatistiksel olarak fark bulunmamaktadır. Çeşit x ekim zamanları interaksiyonlarında en yüksek yağ

oranları, %2,40 ile Deren çeşidinin Kasım ayında yapılan ekimlerinde ve %2,39 ile Deren çeşidinin Aralık ayında yapılan ekimlerinde kaydedilmiştir. Bu iki çeşit x ekim zamanı interkasiyonu, aynı istatistiksel grupta yer almış olup, aralarında istatistiksel olarak fark bulunmamaktadır. Yağ oranı en düşük çeşit x ekim zamanları interaksiyonları incelendiğinde, %1,40 yağ oranı ile Irmak 01 çeşidinin Mart ayında ekimleri ve %1,42 yağ oranı ile Irmak 01 çeşidinin Şubat ayında yapılan ekimleri, diğer çeşit x ekim zamanları interaksiyonlarının gerisinde kalmıştır. Diğer çeşit x ekim zamanları interaksiyonlarının yağ oranlarının %1,62-2,20 arasında değiştiği Çizelge 8'den görülmektedir. Volobuevaa ve ark (2024), Rusya-Oryol bölgesinde biyolojik ürünlerin ve büyüme düzenleyicilerin iki bezelye çeşidine uygulamalarında yağ oranın %1,5-2,0 arasında değiştiğini belirtmişlerdir. Yürütülen araştırmada yağ oranının ekim zamanının gecikmesiyle azaldığı ve yağ oranları çeşidin genetik özelliğinin yanı sıra, yürütülen araştırmada çevresel faktörlerden etkilendiğini açıklamaktadır.

Sonuç

Yürütülen çalışmada, Deren, Elena ve Irmak 01 bezelye çeşitleri Kahramanmaraş koşullarında Kasım Aralık, Ocak, Şubat ve Mart aylarında ekim yapılarak, tane kalite kriterleri yönünden uygun ekim zamanının belirlenmesi amaçlanmıştır. Araştırmada hasat süresi, bakla bağlama süresi, hasat indeksi, bin tane ağırlığı, nişasta oranı, protein oranı, yağ oranı incelenmiştir. Bezelye çeşitleri nişasta oranlarına, protein oranlarına, yağ oranlarına, bakla bağlama sürelerine göre önemli derecede farklılıklar göstermiştir. Ekim zamanlarını, çeşit x ekim zamanı interaksiyonları bin tane ağırlığı, protein oranları, yağ oranları, bakla bağlama süreleri üzerinde önemli etkide bulunmuştur. Ekim zamanlarının gecikmesi hasat süresini, bakla bağlama süresini kısalırken protein oranını artığı kaydedilmiştir. Deren çeşidinin erkenci, protein ve yağ oranın daha yüksek, nişasta oranının oranın düşük, Irmak 01 çeşidinin bin tane ağırlığı ve nişasta oranının yüksek, yağ oranının düşük olduğu belirlenmiştir. Yürütülen çalışmanın bölge ekolojisi yönünden önemli olduğu, erken ekimin önerilmesi ve tekrarlanmasının yararlı olacağı kabul edilmiştir.

Araştırmacıların Katkı Oranı Beyan
Makalede yazarlar eşit katkı hakkına sahiptir.

Çıkar Çatışması Beyanı
Makale yazarları arasında herhangi bir çıkar çatışması bulunmamaktadır.

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Spatiotemporal Dynamics of Li, Mn, Ni, and Ba Concentrations in Sediments of Lotic Habitats in the Biga Peninsula, Türkiye

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Abstract

Sediments, which contain a wealth of various toxic and essential elements, play a very important role in our freshwater habitats. Although some elements are essential and needed by living things, it is known that long-term and large-scale exposure to them can be harmful, just like non-essential toxic elements. The Biga Peninsula, situated in the northwestern region of Anatolia, possesses significant agricultural, industrial, and touristic potential. This study was carried out to determine the spatiotemporal variations of lithium (Li), manganese (Mn), nickel (Ni) and Barium (Ba) levels in sediments of the riverine ecosystems located in the Biga Peninsula. Five riverine ecosystems were selected for the study, and sediment samples were collected during both the dry and wet seasons of 2022–2023 to assess seasonal variations. According to the results of this research, the annually average concentrations of investigated elements in sediments of the riverine ecosystems located in the Biga Peninsula were found in the order of Mn (1076 mg/kg) > Ba (93 mg/kg) > Ni (21 mg/kg) > Li (14 mg/kg). While no significant seasonal differences were detected in Mn, Ni and Ba accumulations, it was recorded that the average Li values in the sediments increased approximately 8 times during the wet season.

Keywords: *Biga Peninsula, Creeks, Sediment quality*

Introduction

Essential elements, such as manganese, are crucial nutrients that play a vital role in the healthy growth and development of all living organisms. However, excessive concentrations of these elements can have detrimental effects on the environment, similar to toxic elements like lithium, nickel, and barium. Therefore, maintaining toxic elements below threshold levels and ensuring a balanced presence of essential elements in aquatic habitats are critical for environmental protection (Haq et al., 2023; Haque et al., 2023; Muhammad et al., 2025). Freshwater sediments serve as key transporters of various pollutants within aquatic ecosystems and provide essential environmental data (Muhammad et al., 2024; Yüksel et al., 2024; Tokatlı et al., 2025). Consequently, analysing the elemental composition of surface sediments is of great importance for understanding and monitoring ecological health (Varol et al., 2022; Ustaoğlu et al., 2022; Köse et al., 2023).

The Biga Peninsula, situated in the northwestern part of Anatolia, possesses considerable agricultural, industrial, and touristic potential due to its fertile soils, strategic geographic location, and abundant natural resources. The peninsula forms part of the eastern connection between Anatolia and Rumelia, divided by the Çanakkale Strait. The region's favourable climate and productive soil support diverse agricultural activities, including the cultivation of various crops, fruits, and vegetables, which substantially contribute to both local and national economies. Agriculture plays a dominant role in the local economy, with the development of agricultural activities leading to the establishment of numerous industrial facilities engaged in agriculture-based production. Additionally, the presence of developing industrial zones and manufacturing sectors fosters economic growth, providing employment opportunities and enhancing regional trade. Furthermore, the peninsula's historical heritage, scenic landscapes, and coastal attractions make it an appealing destination for tourism, drawing visitors with an interest in cultural, historical, and nature-based experiences (Anonymous, 2021; Tokatlı et al., 2023; 2024; Varol and Tokatlı, 2024; https://www.biga.bel.tr/; https://www.gelibolu.bel.tr/; http://www.biga.gov.tr/; http://www.gelibolu.gov.tr/).

Due to these characteristics of Biga Peninsula, investigating sediment quality is crucial for both human and ecosystem health. In this research, accumulations and spatiotemporal distributions of lithium (Li), manganese (Mn), nickel (Ni) and Barium (Ba) in sediments of the riverine habitats of Biga Peninsula were investigated.

Materials and Methods

Research area and sample collection

Five fluvial habitats were selected across the Biga Peninsula (Figure 1). Surface sediment samples were then collected during the dry (late summer) and wet (late winter) seasons of 2022–2023 using a Hydrobios branded Ekman Grab (EPA, 2001a).

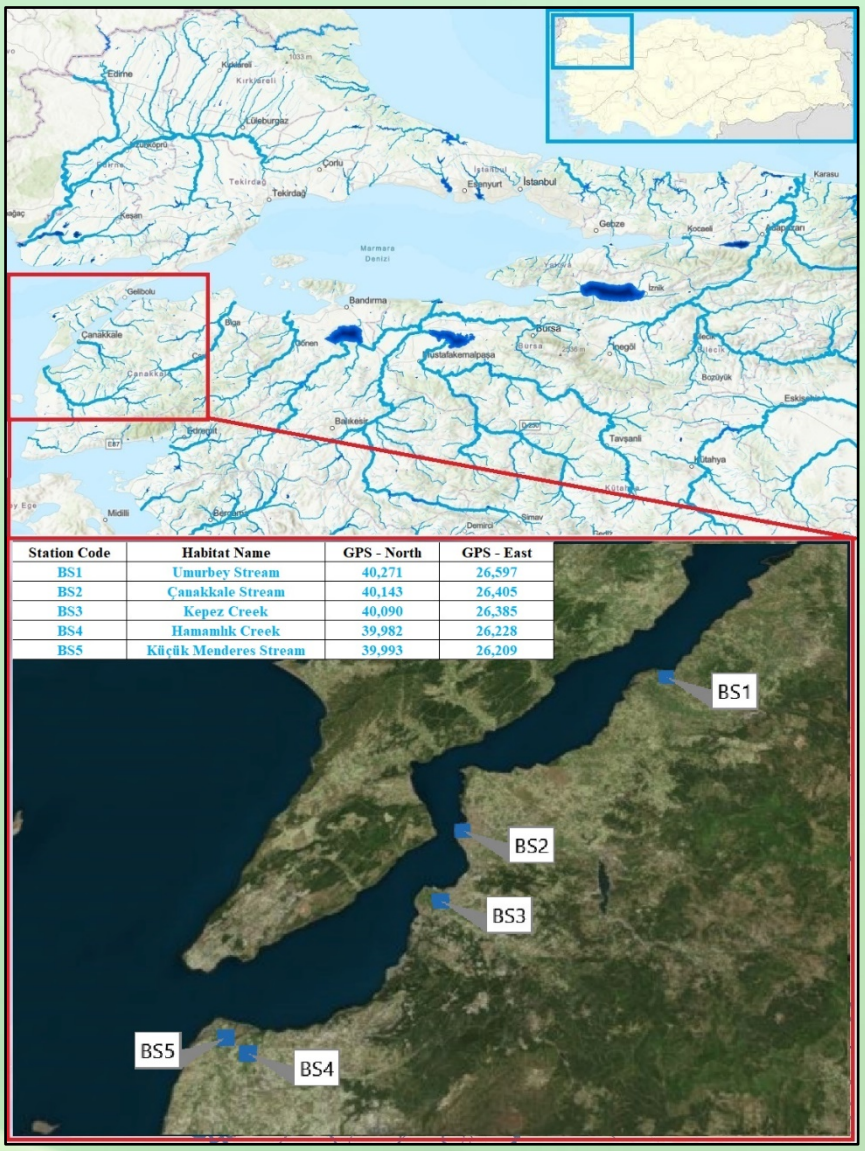


Figure 1. Research area and selected sampling stations

Macro – micro element analysis

To quantify the concentrations of lithium (Li), manganese (Mn), nickel (Ni), and barium (Ba) in the sediment samples, each sample was first dried for 3 hours at 105°C. A 0.25g aliquot of each dried sample was then placed into a CEM Mars Xpress microwave digestion system. To initiate the digestion process, a mixture of acids ($HClO_4$ and HNO_3 in a 1:3 ratio) was added to the reactors (Pyrex). The samples were subsequently subjected to mineralization by heating at 200°C for 30 minutes. After the mineralization process, the samples were filtered through a 0.45 µm cellulose nitrate filter. The filtrates were then diluted to a final volume of 100 ml with ultrapure water. The elemental concentrations in the samples were measured using an Agilent 7700 ICP-MS system, performing triple readings for each sample. The analysis was conducted at the central laboratory of Trakya University (Edirne, Turkey), which is accredited under TS EN / ISO IEC 17025 (EPA, 1998; 2001b).

Results and Discussion

The variations of measured lithium (Li), manganese (Mn), nickel (Ni) and Barium (Ba) concentrations in sediments of riverine habitats located in Biga Peninsula are given in Figure 2. Significant spatial and temporal differences in accumulations of investigated elements were recorded. Average data of the Li, Mn, Ni and Ba levels in sediments of straits basins components in dry and wet seasons as follows respectively: 2 – 14 mg/kg for Li; 1389 – 2357 mg/kg for Mn; 13 – 18 mg/kg for Ni; and 85 –151 mg/kg for Ba. Also, according to the results of this research, the annually average concentrations of investigated elements were found in the order of Mn (1076 mg/kg) > Ba (93 mg/kg) > Ni (21 mg/kg) > Li (14 mg/kg).

The geological characteristics of watersheds can significantly influence the sediment chemistry of aquatic ecosystems, potentially leading to an increase in both essential and toxic element concentrations beyond natural thresholds (Çiçek et al., 2013; 2014; Tokatlı and Helvacıoğlu, 2020; Tokatlı and İslam, 2022; Mia et al., 2023; Mutlu et al., 2023). Elevated concentrations of macro elements in aquatic environments serve as indicators of anthropogenic activities and may pose a threat to natural ecosystems (Köse et al., 2023; Tokatlı et al., 2023; Din et al., 2023). Consequently, the relatively high macro element contents detected in sediments at certain locations are likely attributable to the geological composition of the region and human-induced influences.

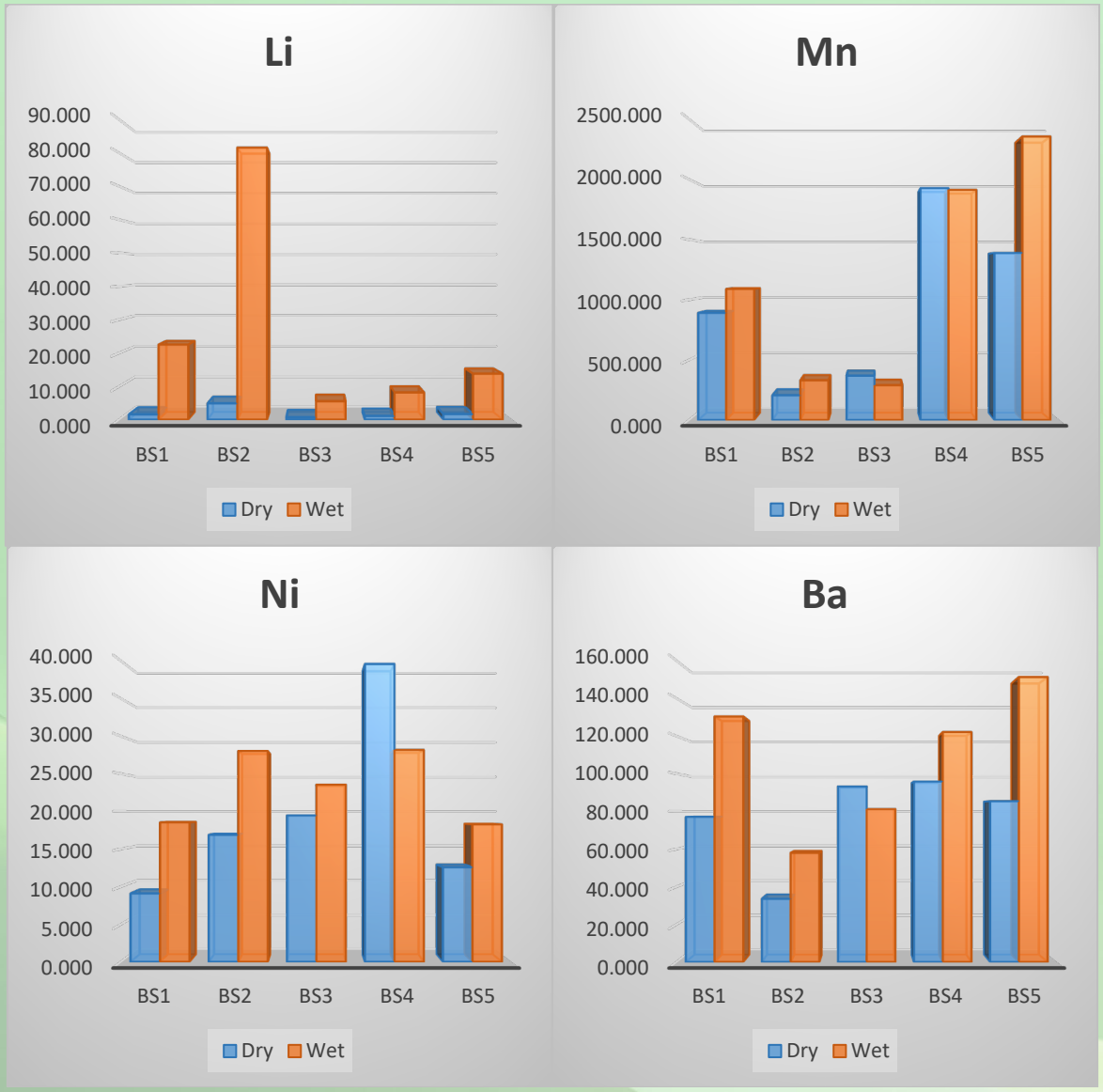


Figure 2. Detected element levels

Conclusions

The results of this study indicate significant spatial and temporal variations in the concentrations of lithium (Li), manganese (Mn), nickel (Ni), and barium (Ba) in the sediments of riverine habitats located in the Biga Peninsula. The observed differences between dry and wet seasons suggest that seasonal factors, such as rainfall and runoff, may influence the distribution and accumulation of these elements in sediments. The average concentrations of Mn, Ba, Ni, and Li were found to vary significantly, with Mn exhibiting the highest levels across both seasons. Specifically, Mn concentrations ranged from 1389 mg/kg in the dry season to 2357 mg/kg in the wet season, highlighting its dominant presence in the sediments of these riverine habitats. Conversely, lithium, with a range of 2 to 14 mg/kg, exhibited the lowest concentrations. The order of average concentrations—Mn > Ba > Ni > Li—reflects the relative abundance of these elements in the environment and emphasizes the importance of manganese in this context. These findings suggest that while some elements, such as Mn and Ba, are more prevalent in the sediment, other elements like Li and Ni may be influenced by different environmental processes or sources. Further research is needed to understand the underlying mechanisms driving these variations and to assess the potential impacts on the local ecosystem.

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Çökelek Peyniri Üretiminde Farklı Starter Kültür Kullanımı

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Peynir, süt ürünleri içerisinde en fazla çeşitliliğe sahip olan üründür. Ülkemizde en çok tüketilen peynir çeşitleri Beyaz ve Tulum olmakla birlikte, özellikle kırsal bölgelerde en çok tüketilen peynir çeşitlerinden biri de çökelek peyniridir. Çökelek peyniri, genellikle aile işletmelerinde geleneksel yöntemlerle üretilmekte ve Türkiyede çoğunlukla semt pazarlarında satışı yapılmaktadır. Çökelek peyniri ülkemizin farklı bölgelerinde yaygın şekilde üretilmekte ve üretildiği bölgenin özelliklerine ve üretim koşullarına bağlı olarak farklı isimlerle de adlandırılmaktadır. Çoğunlukla geleneksel olarak yoğurttan üretilen bu peynir çeşidi, süt, peyniraltı suyu, yayıkaltı ve ayrandan da üretilebilmektedir. Üretim prosesi bakımından büyük farklılık göstermeyen çökelek üretiminin temel aşaması, üretiminde kullanılan hammaddeye çeşitli pıhtılaştırıcıların eklenmesi (enzim, kültür ya da çiğ sütün doğal florası ile asitiliğin ilerletilmesi) ardından kaynatılması ve elde edilen pıhtının süzülmesi şeklindedir. Üretilen peynir çeşidinden bağımsız olarak, uygun başlangıç kültürlerinin dikkatli bir şekilde seçilmesiyle peynirin dokusunu ve tadını geliştirmek, peynir endüstrisinin büyümesini ilerletmek için önemli bir yöntemdir. Laktozdan laktik asit üretmek peynir yapımındaki en önemli adımdır. Starter kültürler, ürüne istenen tadı, aromayı ve yapıyı sağlayan belirli özelliklere sahip mikroorganizmalardır. Süt endüstrisinde standart ve kaliteli ürünlerin üretimi, uygun özelliklere sahip başlangıç kültürlerinin kullanılmasına bağlıdır. Starter kültürlerin ürünün lezzetini artıran bileşikler ürettiği bilinmekle birlikte, taze peynirler genellikle benzer lezzet ve aromaya sahiptir. Bu nedenle, taze fermente ürünlerin üretiminde başlangıç kültürünün seçimi, tüketicilerin tat ve aroma algısını şekillendirmede oldukça önemlidir. Bu düşünceden yola çıkarak, bu çalışmada çökelek peyniri üretimde 3 farklı ticari starter kültür kullanılmış ve elde edilen peynir örneklerinin mikrobiyolojik, fizikokimyasal, tekstürel ve duyusal özellikleri karşılaştırmalı olarak incelenmiştir.

Anahtar kelimeler: *Çökelek peyniri, starter kültür, DVS kültür*

ID: 425

Determinants Of Choice Of Marketing Outlet For Edible Insects Among Smallholder Farmers And Traders In Western Kenya

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Abstract

The edible insect sector has, in recent times, gained significant prominence and attention. Particularly, the government of Kenya has made remarkable steps to achieve a potentially large and valuable edible insect market, with a significant milestone being the passing of regulations on edible insects as a new source of proteins. However, research on the edible insect marketing environment is still indistinct. Therefore, the study sought to evaluate the determinants of the market outlets preferred or used by smallholder farmers and traders of domesticated and field-collected edible insects (including cricket, bees, winged termites, lake flies, and dung beetle) in Siaya and Vihiga counties. This cross-sectional study was done among 188 edible insects' farmers and traders. Purposive sampling identified the study area, while snowball sampling reached the study participants. Data was collected using structured questionnaires and analyzed using multinomial logit regression to assess independent-dependent variable relationships, yielding marginal effects. Study findings showed that at 95% confidence interval, the yield was significant to the three outlets used by the farmers. Gender was significant to both institution and open-air markets outlets but insignificant to selling at the farm gate. Age, education level, and experience in marketing were insignificant to all the three market outlets. Marketing training was significant to the institution and open-air markets**.** The study also showed that farmers and traders had limited choices to sell their edible insect produce, which was majorly affected by yield and age variables. In view of these findings, enhancing edible insect marketing and training through initiatives that would increase production among farmers and breaking the attitudes toward open-air marketing among male farmers is pivotal to the thriving of the novel food enterprise towards achieving food security in the region.

ID: 426

Spatiotemporal Dynamics of Li, Mn, Ni, and Ba Concentrations in Sediments of Lotic Habitats in the Gelibolu Peninsula, Türkiye

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Abstract

Sediments, rich in various toxic and essential elements, play a crucial role in freshwater habitats. While some elements are necessary for living organisms, prolonged and large-scale exposure to them—similar to non-essential toxic elements—can be harmful. The Gelibolu Peninsula, situated in the northwestern part of Anatolia, holds significant agricultural, industrial, and touristic potential due to its fertile lands, strategic location, and rich natural resources. This study was carried out to determine the spatiotemporal variations of lithium (Li), manganese (Mn), nickel (Ni) and Barium (Ba) levels in sediments of the riverine ecosystems located in the Gelibolu Peninsula. Three riverine ecosystems were selected for the study, and sediment samples were collected during both the dry and wet seasons of 2022–2023 to assess seasonal variations. According to the results of this research, the annually average concentrations of investigated elements in sediments of the riverine ecosystems located in the Gelibolu Peninsula were found in the order of Mn (708 mg/kg) > Ba (52 mg/kg) > Ni (22 mg/kg) > Li (15 mg/kg). While no significant seasonal differences were detected in Mn, Ni and Ba accumulations, it was recorded that the average Li values in the sediments increased approximately 4 times during the wet season.

Keywords: *Gelibolu Peninsula, Creeks, Sediment quality*

Introduction

The presence of certain elements in the environment is essential for sustaining life, as they contribute to the growth and development of all living organisms. However, when these elements, including manganese, accumulate in excessive concentrations, they can negatively impact ecosystems, much like toxic elements such as lithium, nickel, and barium. Therefore, ensuring that toxic elements remain below critical limits and that essential elements are present in balanced amounts within aquatic habitats is crucial for environmental preservation (Haq et al., 2023; Haque et al., 2023; Muhammad et al., 2025). Freshwater sediments act as major carriers of pollutants in aquatic ecosystems and offer valuable insights into environmental conditions (Muhammad et al., 2024; Yüksel et al., 2024; Tokatlı et al., 2025). Thus, examining the elemental composition of surface sediments is fundamental for assessing and monitoring ecological health (Varol et al., 2022; Ustaoğlu et al., 2022; Köse et al., 2023).

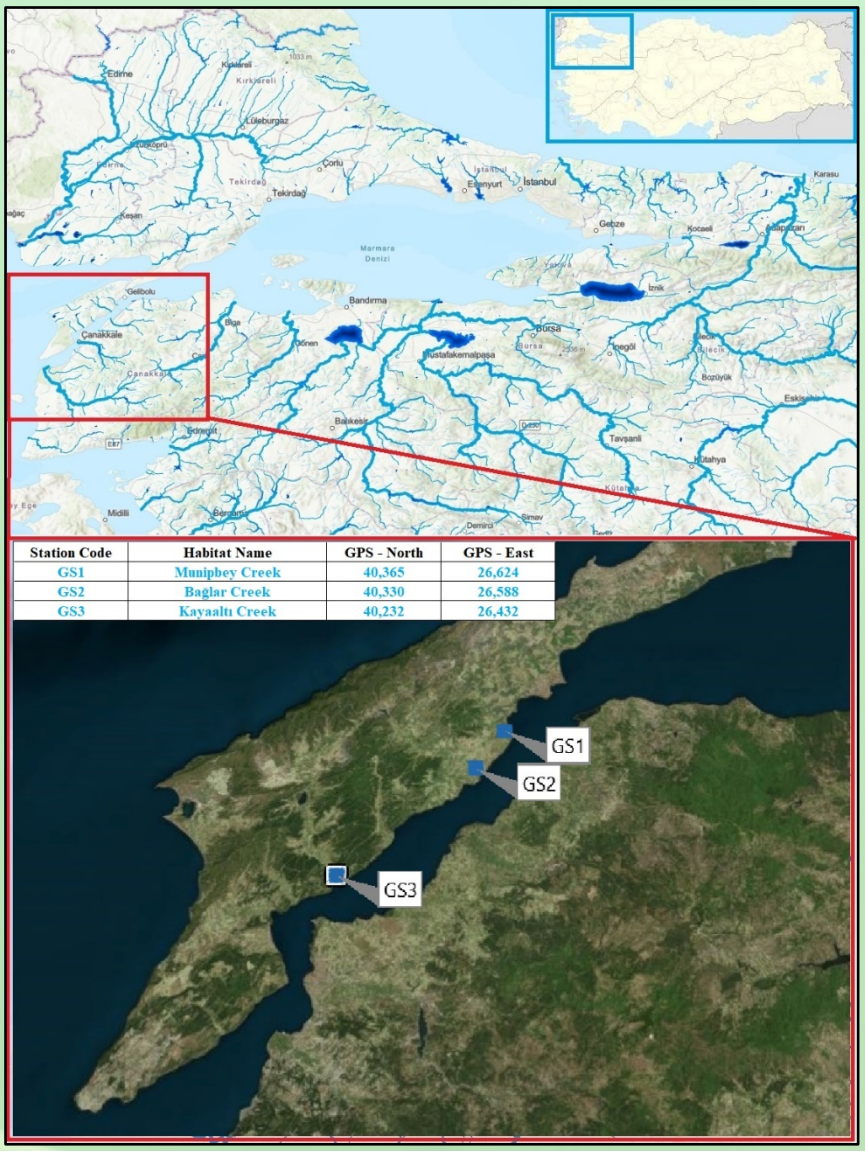
The Gelibolu Peninsula, located in the northwestern region of Anatolia, offers considerable agricultural, industrial, and touristic potential, owing to its strategic geographical position, fertile lands, and abundant historical and natural resources. Positioned in the southern part of East Thrace, the European region of Türkiye, with the Aegean Sea to the west and the Çanakkale Strait to the east, the peninsula benefits from a favourable climate and productive soils that support a diverse array of agricultural activities. These include the cultivation of various crops, fruits, and vegetables, which contribute substantially to both local and national economies. The region's agriculture-based economy is further strengthened by the development of numerous industrial facilities that engage in agriculture-based production. Additionally, the Gelibolu Peninsula has a well-established fishing industry, with many fish canning facilities operating in the area. The presence of developing industrial zones, along with the region's historical significance, scenic coastal landscapes, and cultural heritage, also make it a prominent tourism destination, attracting visitors interested in both historical exploration and nature-based experiences (Anonymous, 2021; Tokatlı et al., 2023; 2024; Varol and Tokatlı, 2024; https://www.biga.bel.tr/; https://www.gelibolu.bel.tr/; http://www.biga.gov.tr/; http://www.gelibolu.gov.tr/).

Due to these characteristics of Gelibolu Peninsula, investigating sediment quality is crucial for both human and ecosystem health. In this research, accumulations and spatiotemporal distributions of lithium (Li), manganese (Mn), nickel (Ni) and Barium (Ba) in sediments of the riverine habitats of Gelibolu Peninsula were investigated.

Materials and Methods

Research area and sample collection

Three fluvial habitats were selected across the Biga Peninsula (Figure 1). Surface sediment samples were then collected during the dry (late summer) and wet (late winter) seasons of 2022–2023 using a Hydrobios branded Ekman Grab (EPA, 2001a).



Station Code	Habitat Name	GPS - North	GPS - East
GS1	Munipbey Creek	40,365	26,624
GS2	Baglar Creek	40,330	26,588
GS3	Kayaaltı Creek	40,232	26,432

Figure 1. Research area and selected sampling stations

Macro – micro element analysis

To quantify the concentrations of lithium (Li), manganese (Mn), nickel (Ni), and barium (Ba) in the sediment samples, each sample was first dried for 3 hours at 105°C. A 0.25g aliquot of each dried sample was then placed into a CEM Mars Xpress microwave digestion system. To initiate the digestion process, a mixture of acids ($HClO_4$ and HNO_3 in a 1:3 ratio) was added to the reactors (Pyrex). The samples were subsequently subjected to mineralization by heating at 200°C for 30 minutes. After the mineralization process, the samples were filtered through a 0.45 µm cellulose nitrate filter. The filtrates were then diluted to a final volume of 100 ml with ultrapure water. The elemental concentrations in the samples were measured using an Agilent 7700 ICP-MS system, performing triple readings for each sample. The analysis was conducted at the central laboratory of Trakya University (Edirne, Turkey), which is accredited under TS EN / ISO IEC 17025 (EPA, 1998; 2001b).

Results and Discussion

The variations of measured lithium (Li), manganese (Mn), nickel (Ni) and Barium (Ba) concentrations in sediments of riverine habitats located in Gelibolu Peninsula are given in Figure 2. Significant spatial and temporal differences in accumulations of investigated elements were recorded. Average data of the Li, Mn, Ni and Ba levels in sediments of straits basins components in dry and wet seasons as follows respectively: 5 – 19 mg/kg for Li; 571 – 523 mg/kg for Mn; 21 – 15 mg/kg for Ni; and 23 – 26 mg/kg for Ba. Also, according to the results of this research, the annually average concentrations of investigated elements were found in the order of Mn (708 mg/kg) > Ba (52 mg/kg) > Ni (22 mg/kg) > Li (15 mg/kg).

The geological composition of watersheds plays a crucial role in shaping the sediment chemistry of aquatic ecosystems, often leading to an increase in both essential and toxic element concentrations beyond their natural baselines (Çiçek et al., 2013; 2014; Tokatlı and Helvacıoğlu, 2020; Tokatlı and İslam, 2022; Mia et al., 2023; Mutlu et al., 2023). Elevated macro element concentrations in aquatic habitats are widely recognized as indicators of anthropogenic influence and can have detrimental effects on natural ecosystems (Köse et al., 2023; Tokatlı et al., 2023; Din et al., 2023). Therefore, the relatively high macro element levels observed in sediments at specific locations are likely a consequence of both underlying geological formations and human activities within these regions.

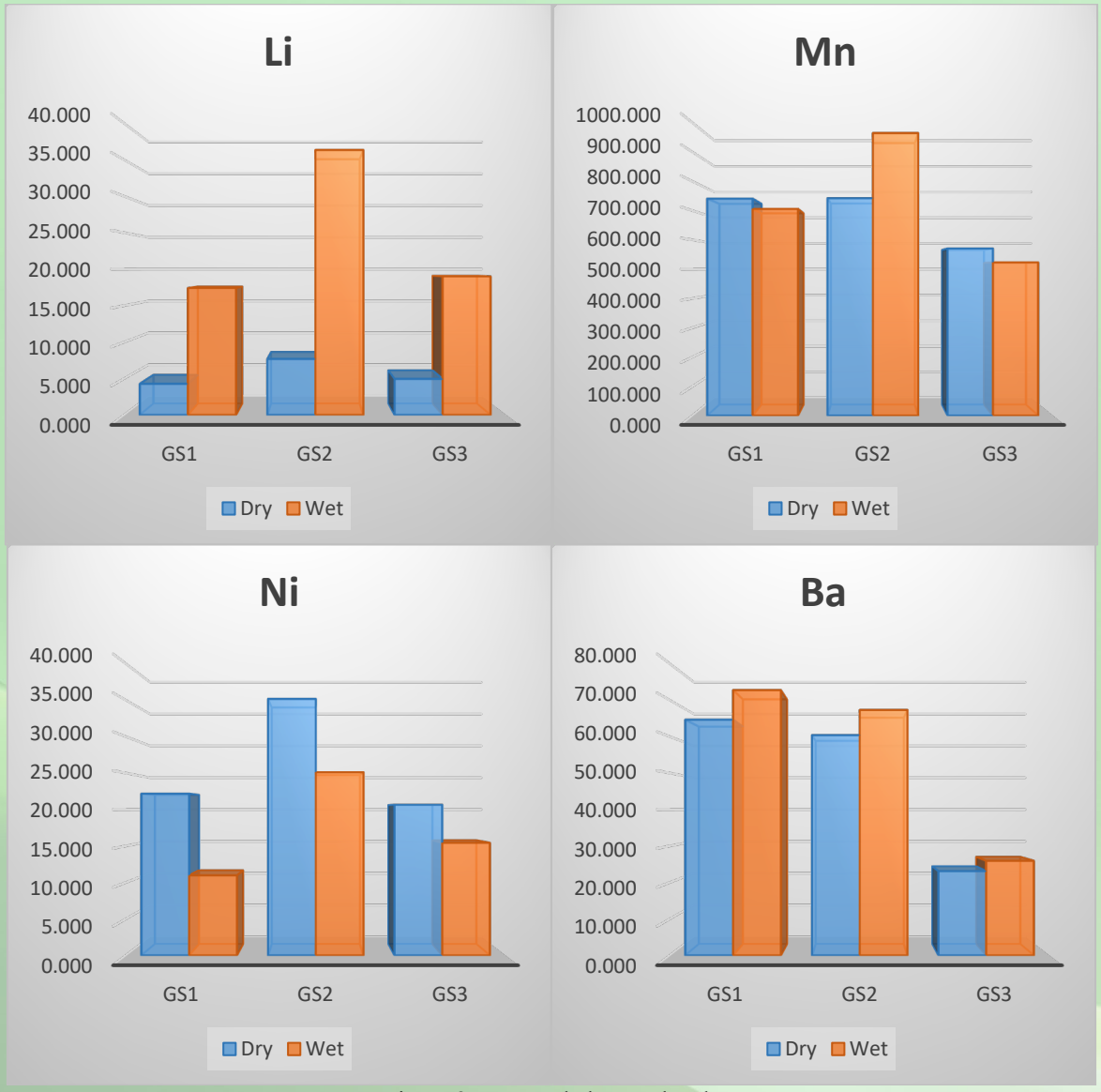


Figure 2. Detected element levels

Conclusions

The findings of this study reveal notable spatial and temporal variations in the concentrations of lithium (Li), manganese (Mn), nickel (Ni), and barium (Ba) in the sediments of riverine habitats in the Gelibolu Peninsula. These differences, observed between the dry and wet seasons, suggest that seasonal fluctuations, such as changes in rainfall, water flow, and sediment transport, significantly influence the distribution and accumulation of these elements. The concentrations of Mn, Ba, Ni, and Li were found to vary across the seasons, with manganese exhibiting the highest concentrations. Specifically, Mn levels ranged from 571 mg/kg in the dry season to 523 mg/kg in the wet season, indicating a relatively high and stable presence in the sediments throughout the year. In contrast, lithium had the lowest concentrations, ranging from 5 to 19 mg/kg. The average concentration levels for the elements in the sediments were found in the following order: Mn > Ba > Ni > Li. This pattern reflects the relative abundance of these elements in the environment and suggests that manganese plays a dominant role in the sediment chemistry of the Gelibolu Peninsula. The findings highlight the need for further research to explore the environmental factors influencing these variations and their potential implications for the local ecosystem and water quality management.

Acknowledgements

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ID: 427

The effect of the addition of shalgam beverage residual product setik on the physical properties of tarhana

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Abstract

The effects of different ratios (5%, 10%, 15% and 20% residual setic powder addition) of setik (bulgur flour) on the physical properties of the product were investigated in tarhana production. In color analysis, compared to the control sample, L* (brightness) value decreased and a* (redness) value increased with the addition of setik powder. Especially 20% setik powder addition (Se-Tose4) provided the highest redness value. b* (yellowness) value decreased as the amount of setik powder increased and the Se-Toz4 sample showed the lowest value. When water holding capacity, foam holding capacity and stability values were analyzed, it was observed that the addition of setik powder increased the water holding capacity and these results were statistically significant ($P<0.05$). Different changes were observed in foam holding capacity and stability values ($P<0.05$). These findings indicate that the use of setik powder in tarhana formulations affects the physical properties of the product and determination of optimum ratios is important for product quality.

Keywords: *Waste product, Setik, Shalgam beverage, Tarhana*

Şalgam suyu artık ürünü setik ilavesinin tarhananın fiziksel özellikleri üzerine etkisi

Özet

Tarhana üretiminde farklı oranlarda (%5, %10, %15 ve %20 artık setik tozu ilavesi) setik (bulgur unu) ikavesinin ürünün fiziksel özellikler üzerindeki etkileri incelenmiştir. Renk analizlerinde, kontrol örneği ile karşılaştırıldığında, setik tozu ilavesi ile L* (parlaklık) değeri düşerken, a* (kırmızılık) değeri artmıştır. Özellikle %20 setik tozu ilavesi (Se-Toz4) en yüksek kırmızılık değerini sağlamıştır. b* (sarılık) değeri ise setik tozu miktarı arttıkça azalmış, en düşük değeri Se-Toz4 örneği göstermiştir. Su tutma kapasitesi, köpük tutma kapasitesi ve stabilitesi değerleri incelendiğinde, setik tozu ikavesinin su tutma kapasitesini artırdığı görülmüş ve bu sonuçlar istatistiksel olarak önemli bulunmuştur ($P<0.05$). Köpük tutma kapasitesi ve stabilitesi değerlerinde ise farklı değişimler gözlenmiştir göstermektedir ($P<0.05$). Bu bulgular, tarhana formülasyonlarında setik tozu kullanımının ürünün fiziksel özelliklerini etkilediğini ve optimum oranların belirlenmesinin ürün kalitesi için önemli olduğunu göstermektedir.

Anahtar Kelimeler: *Atık ürün, Setik, Şalgam suyu, Tarhana*

ID: 429

Understanding Farmers' Stated Preference for Gold-Mined Degraded Land Restoration

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Abstract

Gold mining activities cause environmental issues and lead to farmland reduction, which calls for the restoration of degraded land. Therefore, this study investigates the influencing factors for farmers' decision to pay for the gold-mined restoration process to have access to more fertile land and to improve the environment. Two hundred forty farmers were randomly selected for the study. The survey design follows a contingent valuation method, and logistic regression is used to analyze the data. The results show that 92.5% of the farmers are willing to pay an average premium of ₦250,313.42 for the land restoration process. Their decision to pay for the restoration process is influenced by their awareness of the negative impacts of land degradation, the size of arable land owned, membership in the cooperative association, higher education, higher income, access to credit, and being male. These findings show the importance of awareness, financial factors, and socioeconomic factors in the land restoration process. Thus, policy design should focus on them for efficient policy intervention to restore degraded land, which could be in the form of awareness creation and financial support.

Key Words: *Gold mining, land degradation, land restoration, stated preference, willingness to pay*

ID: 430

Natural Bee Products for Calf Feeding

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Abstract

The use of antibiotics leaving residues in animal products and its indiscriminate use has led to the ban on their use in animals. Therefore, natural feed additives that are alternatives to antibiotics have gained importance. Nowadays, the search for natural, growth-promoting, and digestion-improving feed additives continues. One of these feed additives, bee products (propolis, pollen, royal jelly, and bee venom), can have a positive effect on performance by increasing animal feed intake, body weight gain, and feed conversion efficiency. Propolis, one of the bee products, can be used in ruminant animal feeding due to its antioxidant, antibacterial, antiviral, and antifungal properties.
The aim of this review is to compile studies on the use of natural bee products, such as propolis, pollen, royal jelly, and bee venom, in calf feeding, their effects on animals, recommended dosages, and the impacts observed in animals.

Key Words: *Bee Products, Calf Feeding, Diarrhea, Growth, Development*

Buzağı Beslemede Doğal Arı Ürünleri

Özet

Antibiyotik kullanımının hayvansal ürünlere kalıntı bırakması ve bilinçsizce kullanımı hayvanlarda kullanımının yasaklanmasına sebep olmuştur. Bu nedenle antibiyotiğe alternatif olan doğal yem katkı maddeleri önem kazanmaya başlamıştır. Günümüzde de doğal, büyüme uyarıcı, sindirim sistemini iyileştirici farklı yem katkı maddeleri arayışlar devam etmektedir. Bu yem katkı maddelerinden biri olan arı ürünleri (propolis, polen, arı sütü ve arı zehiri) hayvanların yem tüketimini, canlı ağırlık artışını ve yemden yararlanma oranını artırarak performans üzerinde olumlu etkiye sebep olabilmektedir. Arı ürünlerinden biri olan propolis ruminant hayvan beslemede antioksidan, antibakteriyel, antiviral ve antifungal özelliğinden dolayı hayvan beslemede kullanılabilmektedir.
Bu derlemede buzağı beslemede propolis, polen, arı sütü ve arı zehri olarak adlandırılan doğal arı ürünlerinin kullanımı olanağı, hayvanlar üzerindeki etkileri kullanım dozları ve hayvanlardaki etkileri hakkında yapılan çalışmaların derlenmesi amaçlanmaktadır.

Anahtar Kelimeler: *Arı Ürünleri, Buzağı Besleme, Ishal, Büyüme, Gelişme*

Giriş

Antibiyotik kullanımının yasaklanmasında sonra gıda güvenliğini artırmak için, hayvan beslemede doğal ürünlere yönelim başlamıştır. Böylece özellikle buzağı beslemesinde arı ürünlerine daha fazla önem verilmiştir (Güner ve Açıkgöz, 2023). Arı ürünleri yalnızca hayvana besin desteği sağlamakla kalmayıp, bazı metabolik hastalıkların önlenmesi ve tedavisinde de destekleyici bir işlev üstlenmektedir. Özellikle apiterapi olarak adlandırılan bu yöntem, buzağılarda farklı hastalıklara karşı doğal tedavi seçenekleri sunmaktadır (Kekeçoğlu ve ark, 2023; Rahimjanova ve ark, 2022; Mert, 2023).
Arıların ürettiği doğal ürünler, insanlar ve hayvanlar için önemli sağlık ve tıbbi faydalar sunan biyolojik olarak aktif maddeler arasındadır. Bu ürünler arasında propolis, polen, arı sütü ve arı zehri bulunmaktadır. Özellikle arı ürünleri, zengin besin bileşenleri ve sağlık için yararlı etkileri ile dikkat çekmektedir. Bu ürünler, yalnızca insanlar için değil, hayvanların sağlığı açısından da sunmuş oldukları besin maddeleri ve sağlık yararları ile öne çıkmaktadır. Arı ürünleri, amino asitler, vitaminler, mineraller ve diğer besin ögeleri açısından zengin olduğu için buzağıların edebilmekte ve bağışıklık sistemini desteklemeye yardımcı olabilmektedir (Topal ve ark, 2018; Ndimballan ve Yücel, 2021). Bununla birlikte; arı ürünlerinin besleyici özellikleri, hayvancılıkta sürdürülebilir alternatif beslenme yöntemlerinin geliştirilmesine olanak tanıyabilmekte ve buzağıların ihtiyaç duyduğu sağlıklı büyüme için etkili birer destek sunarak, onların sağlıklı gelişim süreçlerini güçlendirebilmektedir.
Ana ve petekgözünün kapanmadan önceki 3-7 günlük dönemdeki erkek arı larvalarının besin madde içeriğinden dolayı (toplam protein ana arı larvasında %12.03, erkek arı larvasında %9.47; lipid ana arı larvasında %10.30,

erkek arı larvasında %8.38; toplam esansiyel aminoasit ana arı larvasında 701.84 mg/100 gr, erkek arı larvasında 655.86 mg/100 gr ve toplam serbest yağ asitleri ana arı larvasında 1780.67 mg/100 gr, erkek arı larvasında 1830.07 mg/100 gr) hücre yenilenmesi, sağlık problemlerin giderilmesi ve vücuda enerji vermesi yönüyle hayvan beslemede de kullanılabilmektedir (Topal ve ark, 2018).

Polen, çiçeklerden arılar tarafından toplanarak kovanlarına taşınan ve yüksek protein, vitamin, mineral ile biyoaktif bileşenler içeren bir besin kaynağıdır. Polen hem bitkiler hem de polinatörler için önemli bir biyolojik madde olup, çiçeklerin dişi organları tarafından üretilen mikroskobik erkek gamet hücreleridir. Polenin yüksek besin değeri (yüksek kaliteli protein, yağ, karbonhidrat, vitaminler, mineraller ve bazı bioaktif bileşenler) hem arıların hem de diğer polinatörlerin sağlığı açısından büyük önem taşır (Alaux ve ark, 2010; Baldin ve ark, 2024). Özellikle bağırsak florasının dengelenmesine yardımcı olan polen, buzağıların bağışıklık sistemini güçlendirmektedir.

Arı sütü, kraliçe arının ve larvaların beslenmesinde kritik bir rol oynayan, protein, yağ asitleri ve vitaminler açısından zengin bir arı ürünüdür. İçeriğinde zengin miktarda protein, yağ asitleri, vitaminler ve mineraller bulundurması, arıların sağlıklı bir şekilde gelişimini sağlamada kritik bir rol oynamaktadır (Mutlu ve ark., 2023). Arı sütü, aynı zamanda benzersiz biyolojik bileşenler içerir ve bu bileşenlerin bazıları, antibakteriyel ve immün destekleyici özelliklere sahip olup, buzağıların büyümesini hızlandırırken, sağlıklı bir bağışıklık tepkisini de teşvik etmektedir (Kekillioğlu, 2023).

Arı zehri, bal arısının (Apis mellifera) savunma mekanizması olarak ürettiği biyolojik bir madde olup, birçok önemli bileşen içermektedir. Bu bileşenler arasında melittin, fosfolipaz A2, hiyaluronidaz ve diğer peptitler yer almaktadır. Melittin, arı zehrinin ana bileşeni olup, inflamatuar süreçlerde önemli bir rol oynamaktadır. Bunun yanında, fosfolipaz A2, enzimatik aktiviteleri inhibe ederek hücresel yanıtları etkilemektedir (Seo ve Lee, 2015; Çaprazlı ve Kekeçoğlu, 2021). Arı zehrinin, çeşitli hastalıkların tedavisinde apiterapi yöntemi ile kullanılması, antienflamatuar ve ağrı kesici özellikleri ile ilgilidir (Onbaşli, 2019; El-Didamony ve ark, 2024). Antienflamatuar ve analjezik özellikleri ile arı zehri, bazı hastalıkların tedavisinde kullanılmakta, bağışıklık sistemini desteklerken aynı zamanda buzağıların yaralanmalarından veya inflamatuar durumlarından kaynaklanan rahatsızlıkların giderilmesine yardımcı olabilir. Ancak, arı zehrinin alerjik reaksiyonlara yol açabileceği göz önünde bulundurularak, dikkatli bir şekilde kullanılmalıdır.

Propolis, arıların bitkilerden topladığı reçineli bir madde olarak, kovanın dış etkenlerden korunmasında önemli bir rol oynamaktadır. Propolis flavonoidler, fenolik asitler, terpenoidler ve çeşitli vitamin ve mineralleri içeren zengin bir bileşime sahiptir. İçeriğinde yer alan flavonoidler ve fenolik asitlerden dolayı antibakteriyel, antifungal, antiviral ve antiinflamatuar özelliklere sahip olup hem arıların sağlığına hem de insan sağlığına katkıda bulunduğu bilinmektedir (Ünal ve ark., 2020; Küşümler ve Çelebi, 2021). Propolis, antibakteriyel, antifungal, antiviral ve antiinflamatuar özellikler sergileyerek hem arıların sağlığını hem de buzağıların savunma sistemini güçlendirmektedir. Propolisin buzağıların bağışıklık sistemini destekleyerek hastalıklara karşı direncini artırdığı ve genel sağlık durumunu iyileştirdiği üzerine yapılan araştırmalar, propolisin buzağı beslemedeki önemini vurgulamaktadır (Kara ve ark., 2014).

Polen

Apiterapi ve doğal beslenme bilincinin giderek yaygınlaştığı günümüzde, polen alternatif bir yem katkı maddesi olarak değerlendirilmektedir. Polen, bal arılarının topladığı çiçek polenlerinin, nektar ve arı salgılarıyla birleştirilmesiyle meydana gelen, besin açısından zengin bir arı ürünüdür. Hayvancılıkta, özellikle buzağı beslenmesinde polen kullanımı, buzağının büyüme ve gelişimini desteklemesi açısından önemli bir seçenek olarak değerlendirilmektedir. Polen, %25-35 oranında protein, birçok vitamin, mineral ve antioksidan bileşen barındırır (Sönmez, 2023).

Polen, özellikle genç hayvanlara gıda olarak verildiğinde gelişimleri üzerinde olumlu etkiler gösterebilir. Araştırmalar, polenin yem ile birlikte verilmesinin buzağılarda hayvan performansını yükselttiğini, yemden faydalanma oranını ve canlı ağırlık artışını geliştirdiğini göstermektedir (Arslan ve ark, 2017). Buna ek olarak, polenin bağışıklık sistemini kuvvetlendirme ve metabolizmayı destekleme özellikleri, buzağıların hastalıklara karşı daha dayanıklı olmasını sağlar (Ndimballan ve Yücel, 2021). Polen gibi doğal ürünler, buzağılardaki sağlık sorunlarının önlenmesi ve tedavisinde yardımcı bir işlev görebilir (Güner ve Açıkgöz, 2023). Bal arısı ürünleri, hayvancılıkta sadece gıda olarak değil, aynı zamanda sağlık destekleyici unsurlar olarak da ele alınmaktadır. Polen, hayvanların sağlığını koruyarak ve performanslarını yükselterek önemli bir rol oynamaktadır (Kabiloğlu ve Kocabağlı, 2022).

Polenin buzağılar üzerindeki etkileri, onların genel beslenme durumu ve sağlıkları üzerinde belirgin sonuçlar doğurabilir. Çeşitli çalışmalarda, polen tüketiminin buzağıların bağışıklık sistemine olumlu katkılarda bulunduğu ve genel sağlık durumlarını iyileştirdiği gözlemlenmiştir (Obeidat ve ark., 2013; Maes ve ark., 2016). Polen, bağırsak mikroflorasını dengeleyerek sindirim sağlığını destekler; bunun sonucunda buzağıların huzursuzluk ve enfeksiyonlara karşı daha dirençli hale gelmelerine yardımcı olur (Wang ve ark., 2014; Vaudo ve ark, 2018).

Yapılan araştırmalar, polenin bağışıklık sistemini güçlendirme potansiyeline sahip olduğunu göstermektedir; bu, patojenlere karşı direnci artıran bazı antimikrobiyal bileşiklerin varlığı ile ilişkilidir (Brodschneider ve Crailsheim, 2010; Fowler ve ark, 2022). Ayrıca, polen tüketimi, buzağılarda büyüme, kilo alımı ve genel gelişim üzerinde

olumlu etkiler gösterebilmektedir (Thames ve ark, 2012; Obeidat ve ark, 2013). Özellikle polenin vitamin ve mineral içeriği, buzağıların büyüme dönemindeki gereksinimlerini karşılamalarına yardımcı olmaktadır (Shi, 2011). Bununla birlikte, polen alerjileri gibi bazı potansiyel risklerin de dikkate alınması önemlidir. Polen tüketimi, bazı bireylerde alerjik reaksiyonlara veya sindirim problemlerine yol açabilir (Motamed ve ark, 2013). Dolayısıyla, buzağılara polen takviyesi yaparken dikkatli olunmalı ve uygunsuz yan etkiler gözlemlendiğinde veteriner hekim danışılmalıdır.

Tablo 1. Buzağılarda polen kullanım dozu ve etkileri

Polen kullanım dozu	Etkileri	Kaynak
25 g/gün	Kuru madde sindirimini artırmıştır Besin madde sindirilebilirliği artmıştır	Tu ve ark., 2014
10 g polen/baş/gün	Sindirilebilirliği, beslenme değerlerini, rumen fermantasyon aktivitesini, büyüme performansını, yem dönüşümünü ve ekonomik verimliliği iyileştirmiştir	Mohsen ve ark., 2017
10 g/kg	Kan serumunda tüm immünoglobulin tiplerinin (IgG, IgM ve IgA), toplam protein, albümin, globulin, glikoz, toplam lipidler, toplam kolesterol ve toplam antioksidan kapasitesinin ve kırmızı kan hücreleri, beyaz kan hücreleri artmıştır Üre-N ve kreatinin konsantrasyonları ile AST ve ALT aktiviteleri Canlı ağırlık artmıştır	El-Nagar ve ark., 2023

Arı Sütü

Arı sütü (royal jelly), bal arıları tarafından üretilen besleyici bir maddedir ve kraliçe arıların yanı sıra arı yavrularının gelişiminde önemli bir rol üstlenir. Besin içeriği, sağlık faydaları ve olası kullanımları, birçok bilimsel araştırmada incelenmiştir. Bu araştırmalarda, arı sütü barındırdığı besleyici unsurlar ve biyolojik aktiviteleri ile öne çıkmaktadır. İlk olarak, arı sütü yüksek miktarda protein (%9-18 civarı), şeker (%7-18 civarı), yağ (%3-8 civarı) ve farklı vitaminler ile mineral bileşenler barındırmaktadır (Morita ve ark., 2012; Karimi ve ark., 2023). Bu karışım, arı sütünü besleyici bir gıda olarak vurgulamaktadır. Arı sütü, barındırdığı 10-hidroksi-2-decenoik asit gibi yağ asitleri ile proteinler sayesinde etkili bir antioksidan özellik taşımaktadır. Bu çerçevede, arı sütünün karaciğer ile böbrek sağlığını destekleyebileceği ve oksidatif stresi azaltma yeteneğine sahip olduğu kanıtlanmıştır (Karadeniz ve ark, 2011; Almeer ve ark, 2019).

Arı sütü, buzağıların beslenmesi açısından önemli olabilecek besin bileşenleri sunmaktadır. Yapılan araştırmalar, arı sütü tüketen hayvanların büyüme performanslarında gelişmeler olduğunu göstermektedir. Buzağılar için arı sütü, onların gelişim süreçleri üzerinde belirgin etkinin sağlanmasına yol açmaktadır. Arı sütü, buzağıların erken dönem beslenmelerinde yüksek kaliteli bir protein kaynağı olarak kullanılabilir; bu proteinler, hücre büyümesini ve bağışıklık sisteminin güçlenmesini destekler (Kekeçoğlu ve ark., 2023). Yapılan araştırmalar, arı sütü ve benzeri arı ürünlerinin, buzağıların sindirim sisteminin sağlıklı gelişmesine yardımcı olduğunu ve hastalıklara karşı genel direncini artırdığını göstermektedir (Mutlu ve ark., 2023). Buzağılar üzerinde yapılan çalışmalar, arı sütü takviyesi ile genç hayvanların daha hızlı büyüme oranlarına ve daha iyi bağışıklık yanıtlarına sahip olduklarını göstermektedir (Benzigül ve ark, 2021). Bunların yanı sıra, arı sütü prostaglandin üretimini engelleyen özellikler sergilemekte ve böylece inflamasyon üzerinde olumlu etkiler sağlamaktadır (Sugiyama ve ark., 2011; Kolaylı ve ark., 2016). Bu durum, arı sütünün buzağıların bağışıklık sistemine olumlu etkisini göstermektedir. Özellikle, arı sütünün mikroorganizmalara karşı etkili özellikleri ile enfeksiyon riskini azaltma potansiyelinde olduğu ve hayvan beslemede kullanılabilmektedir (Pasupuleti ve ark., 2017; Maželiėnė ve ark., 2022).

Propolis

Propolis, doğal bir bileşim olan ve arılar tarafından üretilen bir madde olarak, sağlık ile üretim açısından önemli yararlar sağladığı bilinmektedir. Bu madde, biyolojik etkileri itibarıyla buzağıların beslenmesinde önemli bir destek olarak görülmektedir. Propolisin besin içeriği ve beyaz kan hücrelerine faydalı etkisinden dolayı bağışıklık sistemine sağladığı faydalar ve genel sağlık durumunu düzeltme kapasitesi, buzağıların beslenmesinde

kullanılmasını teşvik etmektedir (Shedeed ve ark., 2019). Propolis içerisinde bulunan fenolik bileşenler ve diğer organik bileşikler, onun antioksidan ve anti-inflamatuar özellikler sergilemesine destek olmaktadır (Saad ve ark., 2021). Genç buzağıların bağırsak sağlığının korunması ve sindirim sisteminin desteklenmesi bakımından propolisin yararlı olabileceği öne sürülmektedir (Soltan ve Patra, 2020).

Küresel olarak büyükbaş hayvan işletmelerinde en önemli sorunlar arasında buzağı ishalleri yer almaktadır. Buzağı ishalleri özellikle yeni doğan 2-3 haftalık buzağılarda görülmekte ve *Escherichia coli, Salmonella, Cryptosporidium parvum, rotavirüs, koronavirüs* patojenleri ile ilişkili olabilmektedir (Naylor, 2009; Muktar ve ark., 2015). Propolis ishale sebebiyet veren *Salmonella* ve *E.coli* üzerine etkili olabileceği gibi sindirim sorunlarının azaltılmasına dolayısıyla genel beslenme verimliliğini de artırmaktadır (Sarker ve Yang, 2010; Przybyłek ve Karpiński, 2019; Manav ve Yılmaz, 2021). Propolisin sindirim sistemi üzerinde yarattığı olumlu etkiler; bağırsak florasını dengeleyerek, besin maddelerinin daha iyi emilmesine imkân tanıyacağından buzağıların genel büyüme,gelişme ve canlı ağırlık artışını olumlu yönde etkileyebilmektedir (Soltan ve Patra, 2020; Küşümler ve Çelebi, 2021; Abu-Seida, 2023).

Tablo 2. Buzağılarda propolis kullanım dozu ve etkileri

Propolis kullanım dozu	Etkileri	Kaynak
4 mL propolis ekstraktı (300 mg/mL)	Canlı ağırlık artmıştır Yemden yararlanma oranı azalmıştır Ishalli gün sayısı ve dışkı skorları olumlu etkilenmiştir	Kaliboğlu ve ark., 2023
4 mL propolis ekstraktı	Buzağı sağlığını olumlu etkiemiştir İshal insidansını azaltmıştır	Slanzon ve ark., 2019
2 cc propolis tentürü	Buzağı büyümesi olumlu etkilemiştir Ekonomik kayıplara neden olan neonatal ishalleri önlemektedir	Yücel ve ark., 2015

Arı Zehri

Arı zehri (apitoksin), bal arısı (*Apis mellifera*) tarafından üretilen karmaşık bir doğal karışımdır. Bu zehir birçok biyolojik etkin madde içerir; özellikle peptitler ve enzimler başta gelir. En yaygın bileşenlerden biri melittindir, arı zehrinin yaklaşık %40-60'ını oluşturan bu peptit, hem antimikrobiyal hem de antikanser özelliklere sahip olduğu bilinmektedir (Pascoal ve ark., 2019; Małek ve ark., 2023). Ayrıca, arı zehirinde fosfolipaz A2 gibi enzimler de bulunur; bu enzimler özellikle hücre zarını parçalama yetenekleri ile dikkat çekmektedir (Khalil ve ark., 2021; Yaacoub ve ark., 2023).

Arı zehrinin buzağı yetiştirmede kullanımı, modern hayvancılıkta doğal, sağlıklı ve etkili bir seçenek olarak dikkat çekmektedir. Arı zehri, çok sayıda biyolojik aktivite sergileyen peptit ve proteinler içeren bir bileşen olduğu için hayvan sağlığına katkıda bulunma olasılığı taşımaktadır (Onbaşlı, 2019; Altıntaş ve Bektaş, 2019). Özellikle apiterapi çerçevesinde arı ürünleri, sağlık destekleyici olarak kullanılmakta ve buzağıların gelişiminde, bağışıklık sisteminin güçlenmesinde önemli bir işlev üstlenmektedir (Onbaşlı, 2019; Altıntaş ve Bektaş, 2019). Arı zehrinin enfeksiyonlara karşı koruyucu özellikleri, bağışıklığı artırması ve antimikrobiyal etkinlikleri, buzağıların sağlığını destekleme açısından önemli bir araç olduğunu göstermektedir (Kolaylı, 2017; Eser ve Erat, 2022; Kekeçoğlu ve ark, 2023).

Bunun yanı sıra, arı zehrinin sindirim sistemine sağladığı faydalar ve besin maddelerinin emilimini artırma özelliği, buzağıların beslenme etkinliğini yükselterek daha sağlıklı ve hızlı bir gelişim süreci yaşamalarına katkıda bulunabilir (Kolaylı, 2017; Güner ve Açıkgöz, 2023). Bu çerçevede, arı zehrinin doğal bir besin katkısı olarak değerlendirilmesi, antibiyotiklerin olumsuz etkilerini azaltarak daha sürdürülebilir bir üretim yöntemi sunmaktadır (Tufan ve Evren, 2021; Güner ve Açıkgöz, 2023). Ancak unutulmamalıdır ki, arı zehrinin potansiyel alerjik etkileri ve toksisitesi nedeniyle, kullanımında dikkatli olunması gerekmektedir (Motamed ve ark., 2013; Kekeçoğlu ve ark., 2023).

Tablo 3. Buzağılarda arı zehri kullanım dozu ve etkileri

Arı zehiri kullanım dozu	Etki mekanizması	Kaynak
0,05 mg/kg, 0,1 mg/kg ve 0,2 mg/kg	Buzağı gelişimi olumlu etkilenmiştir. İshal skoru ve kan biyokimyasal profili üzerine etkilidir.	Oh ve ark., 2011

Sonuç

Günümüzde, arı ürünlerinin buzağı beslemedeki kullanımı hem sağlık hem de gelişim üzerinde önemli etkilere sahip bir strateji olarak öne çıkmaktadır. Polen, arı sütü, arı zehri ve propolis, buzağıların bağışıklık sistemlerini güçlendirme, sindirim sağlığını destekleme ve genel gelişim süreçlerini iyileştirme açısından besin madde bakımından zengin içerikler sunmaktadır. Bu doğal ürünlerin entegre bir şekilde kullanılması, buzağı beslemede doğru beslenme uygulamaları ve sürdürülebilir hayvancılığın geliştirilmesi için önemli bir fırsat olabilmektedir. Gelecek araştırmalar, arı ürünlerinin buzağı sağlığına olan katkılarını daha derinlemesine inceleyerek, fiyat fayda analizlerinin yapılarak ekonomik fayda analizleri değerlendirilmesi gerekmektedir. Yapılacak yeni çalışmalarla da bu alandaki bilgi birikimine önemli katkılarda bulunabilmekte ve hayvan besleme alanında yeni stratejilerin geliştirilmesine olanak tanıyabilecektir.

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Seasonal and sexual variation in the length–weight relationship of narrow–clawed (*Pontastacus leptodactylus* Eschscholtz, 1823) crayfish in Eğirdir Lake

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Abstract

The length–weight relationship (*LWR*) is a fundamental aspect of fish biology and fisheries science, providing critical insights into various biological and ecological evolutions, such as growth analysis, stock assessment, health and condition, feeding habits etc… Therefore, accurately determining it is extremely important. The study was conducted in Lake Eğirdir in 2015 to determine the length-weight relationship of Turkey's most important crayfish stock. Seasonal sampling was performed using 200 fyke nets with different mesh sizes. The *LWR* was determined according to Le Cren (1951), and a t-test following Pauly (1984) was used to assess whether the b value differed from 3. The data were analyzed using the R package "ggFishPlots (v 0.3.1)" (Vihtakari, 2025). In the study, 4,035 crayfish with a total length ranging from 35.12 to 155.11 mm and a total weight between 1.20 and 130.80 g were evaluated. The sample comprised 56.90% (2,295) female and 43.10% (1,738) male crayfish, with a D:E ratio of 1.32. The evaluations revealed that female crayfish exhibited negative allometric growth in spring, summer, and autumn, while displaying isometric growth in winter. Male crayfish, on the other hand, showed positive allometric growth in spring, autumn, and winter, but isometric growth in summer. As a result, it was determined that the growth characteristics of crayfish varied by sex and season. In studies utilizing LWR parameters, it is believed that sampling during only one period of the year may lead to misleading results. Therefore, monthly or seasonal sampling would provide more accurate assessments.

Key Words: *Allometric growth, Isometric growth, Growth types, LWR*

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The Application Of Tannin's In Ruminant Nutrition (A Review)

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Abstract

Tannin exists as a group of plant polyphenolic compounds which plays a vital role in animal feeding, especially for ruminants animals that exhibit protein cohesion properties. The hydrolysable tannin (HT) and condensed tannin which are two groups of tannin based on chemical structure were identified. The hydrolysable tannin when digested in the rumen of ruminants may release toxic compounds which when consumed in large quantities expose animals to health risks, while condensed tannin (CT) is the most common form of tannins which several nutritional benefits through the protection of dietary components from too much breakdown in the rumen, therefore enhancing protein use and reduction of Nitrogen (N) excretion. The study further highlighted the effects of tannin on feed intake, palatability, nutrient absorption, bloat prevention actions of tannins, and anti-parasitic functions. The moderate level of tannin in ruminant nutrition can enhance ruminant performance and excess consumption can lead to poor feed consumption with low nutrient absorption. This shows the need for selective diet formulation when including tannins in animal diets. There is a need for researchers to seek for strategic inclusion of tannins in ruminant diets especially types and amounts to optimize ruminant health and productivity. The need for future studies to continue with more understanding of tannin activities within the rumen and ways to develop protocols for effective consumption in ruminant nutrition is paramount.

Key Words: *hydrolysable tannin, condensed tannin, ruminant nutrition,*

Introduction

Tannins are various groups of polyphenolic substances that were identified for their dynamic effects in both plants and animals. In the field of ruminant nutrition, tannins were eminent to have both advantages and drawbacks. Traditionally, tannins' ability to cling to proteins and other feed material, makes it gain the anti-nutritional defects which causes a reduction the nutrient intake as well as its accessibility by the animal (Besharati et al., 2022). Despite these drawbacks, it was discovered that, with control usage of tannins in ruminant diet a positive outcome can be seen. These positive outcomes include; better protein use and animal health, there is also improvement in methane emission as well as a sustainable ruminant animal production (Fonseca et al., 2023).

Both the positive and negative effects of tannins were investigated, among the positive effect was the ability of the tannins to reduce protein and nitrogen loses in the rumen hence rumen improvement (Fonseca et al., 2023). The negative effect were associated with high tannin concentration leading to lower intake and poor digestibility, this make it necessary to be careful in deciding which dose to be given to the animal (Besharati et al., 2022; Price et al, 1980). There are a lot of loopholes on knowing how these tannins from different sources as hydroysable and condensed impact the ruminant animal wellbeing and their ability to enhance their production, even with the above stated results (Price et al, 1980).

Despite the tremendous contribution in this area there is still a need for a research that will clearly determine the optimal concentration of tannins to be included in the diet of ruminant animals according to the target production purposes. Also the need to understand the long term effects of tannins on animal wellbeing is eminent as well as the environment (Fonseca et al., 2023).

Therefore, the objective of these study is to carefully analyze the recent studies on the application of tannins in ruminant nutrition, with an emphasis in identifying the optimal condition of their usage to enhance production.

Hydrolysable and Condensed Tannins

Many different types of plants contain polyphenolic compounds known as tannins (TANs). They can be classified as either hydrolysable tannins or condensed tannins based on their chemical structure (Pastorelli, & Salvatori, 2021). Tannins that are hydrolyzable have a central carbohydrate, usually D-glucose. Some phenolic groups, such as gallic acid (gallotannins) or ellagic acid (ellagitannins), partially or completely esterify the hydroxyl groups of these carbohydrates. According to Mueller-Harvey (2001), plants typically contain small levels of hydrolyzable tannins.

According to Waghorn and McNabb (2003), these tannins are present in oak (Quercus spp.), Acacia, Eucalypts, and a variety of browsing and tree leaves. The dry matter (DM) content of the browse including the leaves and apices can range from 200g to 500g, and in certain species, the amount of phenolic compounds can surpass 500g per kg of DM (Lowry *et al.,* 1996). Although hydrolyzable tannins have the potential to be poisonous to animals, most ruminants are able to adapt to eating them (Waghorn and McNabb, 2003). Ruminants can tolerate these poisonous tannins because they can decrease the amount of products they excrete in their urine (Lowry *et al.,* 1996). While ruminants possess this ability, an overindulgence in this tannic diet can cause lesions in the liver and kidneys, as well as cause mortality (Waghorn and McNabb, 2003).

The poisonous substance that is responsible for the first over ingestion usually takes five to ten days to cause death. Rarely is information available on how hydrolyzable tannins are absorbed, digested, and affect metabolism and production. According to Le Bourvellec and Renarda (2012), condensed tannins (CTs) are flavanol units in oligomers or polymers that are usually joined by carbon-carbon bonds at the 4/6 or 4/8 position. These compounds are also called proanthocyanidins because they can degrade oxidatively in an acidic environment to produce anthocyanidin colours. In mild or anaerobic conditions, the polymer is stable, according to Hagerman *et al;* (1992). The amount and location of hydroxyl groups along with the spatial arrangement of atoms in molecules are dealt with by the form of comprise unit. Condensed tannin structure is influenced by the type and location of the connections between sequence monomeric units as well as the degree of polymerization (Dixon *et al.,* 2005). Polymeric units derived from flavanol monomers can take on several shapes. Positive and negative charges are possible for these units. According to Waghorn (2008), the amount of flavanol units in a chain length can vary from dimmers to over 20 flavanol units. Each polymer in temperate forages can consist of many flavan-3-ol structures. The number of flavonoid units in condensed tannins might range from two to fifty. Complex structures are found in condensed tannin polymers because of the various sites for interflaven bonds and the variability of flavonoid units to some substituents. Depending on their chemical makeup and level of polymerization, condensed tannins may or may not dissolve in aqueous organic solvents. Condensed tannin-containing plants are thought to have developed over time to enlist them as a defence strategy, shielding them from insects and grazing animals as well as harmful bacteria (Swain, 1979). These days, they are being taken out of different plants to help with animal health. Previously, acetone-water was used to extract these condensed tannins; however, this approach did not fully remove the CT (Barry *et al.,* 1999). Condensed and hydrolyzable tannins frequently coexist in the same plant (Waghorn, 2008). Hydrolyzable tannins are thought to be harmful to animal nutrition (Serrano *et al.,* 2009). They are polyesters of sugars (mostly glucose) and gallic or ellagic acids (Figure 1). Polymers containing flavan-3-ols are known as condensed tannins (Figure 2). They are also known as proanthocyanidins because they undergo oxidative cleavage, or heating in the presence of acid, to produce vibrant anthocyanidins. The flavan-3-ol subunits that make up each CT polymer can vary, but the most prevalent ones are gallocatechin, epigallocatechin, and catechin, which together create procyanidins and prodelphinidins.

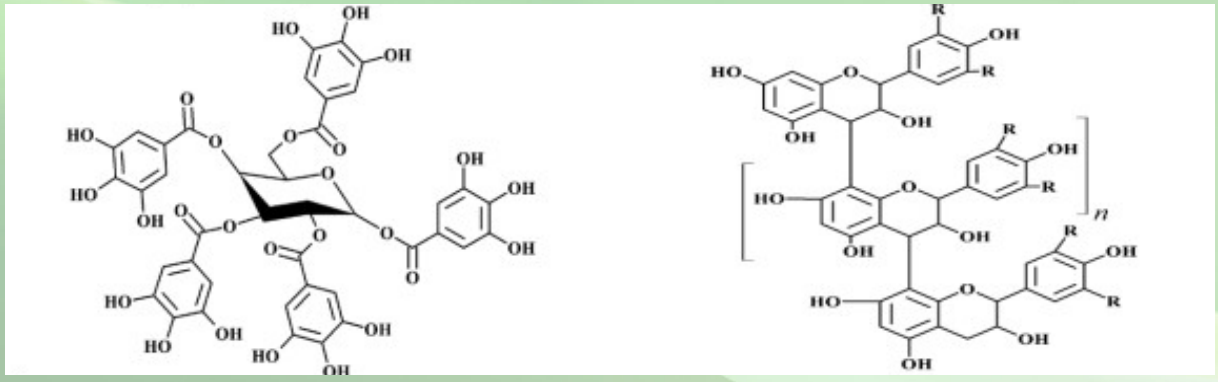


Figure 1. Structure of hydrolysable tannin (Serrano at al, 2009)

Figure 2. Structure of condensed tannin (Serrano at al, 2009)

Tannin Sources and Preference in different types of forages

According to Mueller-Harvey (2006), animal feed including Acacia, Dichrostachys, Dorycnium, Hedysarum, Leucaena, Lotus, Onobrychis, Populus, Rumex, and Salix contains tannin. According to Dixon et al. (2005), they can be found in seeds, fruits, leaves, wood, bark, and roots. The most important plant parts, such as young leaves and flowers, have higher concentrations of tannins (Terril *et al.,* 1992). According to Waghorn and McNabb (2003), the primary drivers of plant tannin synthesis are defence against diseases, energy and nitrogen conservation, and defense against grazing animals. Tannin content varies from 2 to 5% of the fresh weight. Pathological circumstances, water stress, temperature, and nutrient availability can all cause concentration to rise (Treutter, 2006).Tropical forages contain condensed tannins that are believed to stimulate plant growth by decreasing the amount of animal excrement and leaf litter released into the soil (Waghorn and McNabb, 2003). Depending on the plant type, forages containing condensed tannins offer ruminants a variety of advantages. Lotus, for instance, has been shown to be effective in preventing bloat. Other condensed tannins have demonstrated efficaciousness in enhancing live-weight growth (Waghorn *et al.,* 1999).

MECHANISM OF ACTIONS

Hydrolysable and Condensed Tannin interacts with proteins and other dietary components in the rumen

Many tannic effects on biological systems are indicated by research findings. Chemical structure determines biological properties (Patra and Saxena, 2010), and according to Waghorn and McNabb (2003), it can even have a greater influence than concentration. Large structural differences exist amongst individual tannins, which explains this. Per Patra and Saxena (2011), tannins with a lower molecular weight have higher protein reactivity. The concentration of both tannins, their molecular weight, the size, conformation, and amino acid composition of the protein, as well as the solvent, temperature, and pH of the medium in which the interactions occur, all have an impact on protein tannin complexes' properties (Le Bourvellec and Renarda, 2012). Due to their capacity to create stable hydrogen bonds between pH 3.5 and 8, they mostly affect proteins (Jerónimo *et al.,* 2016).The nature of the complexes that form between proteins and tannins in sainfoin (Onobrychis viciifolia) was investigated by Jones and Mangan (1977) using both in vitro and in vivo methods. The pH range of the rumen is between 5.7 and 7.3, and protein complexes were stable in vitro between pH 3.5 and pH 7.0. Then, as the pH changed—the abomasum pH is less than 3.5—complexes separated. Because of their detrimental effects on protein intake, digestion, and palatability, as well as on polysaccharides and minerals, tannins were long regarded as antinutritive substances. According to Crozier *et al*; (2009), frequent usage of tannin was also found to be hazardous due to damage to the kidney, liver, rumen tissue, and microvilli morphological abnormalities. According to Murdiati *et al;* (1992), the HT primarily had a negative impact on body tissue because they are enzymatically depolymerized in the rumen to gallic acid, which is then further metabolised by microbes to pyrogallol and other low molecular weight phenols that are absorbed and cause cellular damage. It is unlikely that condensed tannins may harm organs because they are not broken down and absorbed into the bloodstream. Digestion of proteins and carbohydrates is linked to a decrease in voluntary intake and their negative effects. In vitro results were validated by trials conducted on sheep that were fed sainfoin.

According to Jones and Mangan (1977), the tannin protein complexes broke apart in the duodenum but remained stable in the rumen (pH 6.5). This gave rise to the theory that tannin–protein complexes are created in the rumen and become available for gastric or pancreatic digestion when the pH drops below 3.5 (in the abomasum, pH 2.5–3) or rises above 8 (in the duodenum, pH 8). Quebracho tannins were also found by Makkar and Becker (1996) to accelerate the rate of inactivation at pH 11. The findings implied that the tannins are rendered inactive by an alkaline pH. Because of the feeding of tannin-rich feeds, the rumen's pace and extent of protein decomposition have diminished, which may have the effect of lowering ammonia concentrations and, consequently, urea N excretion in the urine(West, 1993). Particular attention has been paid to condensed tannins because, depending on the source, they may contribute significantly to the nutritional value of feed, the calibre of products acquired, and the overall health and welfare of animals when present in diets at low-to-moderate concentrations. Enhancing the digestive utilisation of feed proteins is one of the most significant benefits of CT use for ruminants. The impact of dietary tannins in ruminants may be advantageous or harmful, depending on variables like tannin chemical structure and concentration in the diet, the makeup of the basal diet, and other factors that are intrinsically related to the animals, like species and physiological stage (Piluzza *et al.,* 2014).

Biochemical pathways affected by Tannins

Nutrients in ruminants undergo fermentative digestion by rumen microbes first. Products of the microbial fermentation eventually become accessible for animal tissue metabolism as protein in the form of microbial cells and energy in the form of volatile fatty acids (Bunglavan, 2013). The ability of tannins to connect with proteins is a key characteristic that accounts for many of their biological actions (Hagerman and Butler, 1991). According to Bernays *et al*. (1989), they can be harmful to a variety of bacteria and fungi, which may be a primary factor in their evolution (Aerts *et al.,* 1999). Many leguminous fodder plants, herbs, and grasses, such as Onobtychis viclifolia (sainfoin), Lotus (L.) corniculatus (birdsfoot trefoil), L. pedunculatus (big trefoil), Hedysarum coronarium (sulla), and Lespedeza cuneata (sericea lespedeza), have intense tannin deposits in their epidermis at varying concentrations (Terrill *et al.,* 1989). Remarkably, it has been documented that plants with higher tannin concentrations yielded less leaves in comparison to those with lower tannin concentrations (Coley, 1986). Proteins in feed become quickly soluble when ruminants are fed forages with a high protein concentration. High ammonia levels result from the breakdown of proteins in the rumen by rumen bacteria. A significant amount of ammonia is taken up from the rumen and expelled in the urine (Ulyatt *et al.,* 1975). Certain tannins have the ability to decrease the quantity of protein that is broken down in the rumen and increase the quantity of protein that is accessible for digestion in the small intestine (Frutos *et al.,* 2004).Tannins and proteins combine to generate complexes. This is because phenolic groups are abundant and can form bonds with the carbonyl groups of peptides. Complexes are resistant to rumen microbe hydrolysis and deamination. More dietary amino acids are becoming available for post-ruminal absorption as a result of stable complexes. Complexes are thereafter accessible in the abomasum and undergo intestinal digestion (Bunglavan and Dutta, 2013).

IMPACT ON DIGESTION EFFICIENCY

Tannins influence on Ruminant Nutrition and Absorption

The impact of quebracho tree tannin extract on Angus steers and heifers was investigated by Beauchemin *et al*. in 2007. Research revealed that average daily gain (ADG), body weight, or nutritional intakes were unaffected by feeding with quebracho tannin extract. Moreover, it did not affect the digestion of DM, energy, or fibre (neutral and acid detergent fibre). Mezzomo *et al;* 2017 examined the effects of substituting soybean meal treated with a tannin mixture (85% CT and 15% HT) on the intake, digestibility, carcass traits, and performance of young cattle fed a diet high in concentrates. Replacing soybean meal with soybean meal treated with tannin resulted in a linear decrease in the consumption of DM. There was no discernible drop in carcass weight. A decrease in fat deposition and a rise in muscle were observed in the carcass gain composition. When tannins are used, animals' body gain composition changes and their consumption of DM decreases, improving feed conversion efficiency (Mezzomo *et al.,* 2017). When fed a high-grain diet supplemented with roughly 0.84 g tannin kg-1 body weight (BW), Frutos *et al.* (2004) showed no effect of chestnut tannin (HT) on lamb carcass qualities; there was also no effect of HT supplementation on ADG, feed efficiency, and length of finishing phase.

To feed young bulls (HT), Doce *et al.* (2007) employed oak leaves. According to the experiment's findings, giving the animals up to 5 kg of tannin per day had no discernible negative effects on ruminal fermentation or toxicity. When dairy crossbred cows were provided a 40 g HT supplement per day, Ali *et al.* (2017) discovered that the milk production increased considerably. Additionally, they saw that adding HT increased the amount of lactose (%) and milk protein. According to Dubey's (2007) findings, crossbred cows' milk output increased significantly from 9.44 to 10.35 kg/day/cow when 3% tannin from Acacia nilotica pods was added. In ewes grazing Lotus corniculatus during the early stages of lactation, Kushwaha *et al.* (2012) found no effect of CT; however, during the mid- and late-lactation stages, there was an increase in milk output of two litres. A research on Friesian dairy cows fed Lotus corniculatus was done by Woodward *et al.* (2000). When lotus was fed to cows instead of ryegrass, the increase in milk yield was noticeably higher (46%). While tannins had no influence on intake, they did enhance the concentration of milk protein, improve efficiency, and decrease the concentration of milk fat. The milk output of cows fed 88 g CT per kg DM increased by 10%, according to Anantasook *et al.* (2014). Comparing crossbred cows fed 1.5% CT per kg DM to cows not provided CT in their ration, Dey *et al.* (2014) found that the latter group's milk output decreased by 24.7%. Conversely, when cows were fed 244 g of tannins (CT) per day, Grainger *et al.* (2009) saw a drop in milk production of 29.7%. Grazing animals consume a vast range of vegetation, yet they frequently favour some while avoiding others. Taste, smell, and chemosensory irritation are the three anatomically unique chemical senses that animals use to decide which plants to consume. (Beauchamp and Mennella, 2009). Physical and chemical properties of feed define its flavour, and during consumption, post-stomach impacts of toxins and nutrients combine with flavour cues to influence palatability (Atwood *et al.,* 2001). According to a number of studies, saliva has a significant impact in how taste and texture sensations are perceived (Engelen *et al.,* 2007). The composition of saliva can affect how feed is perceived while also being influenced by the type of diet (Mese and Matsuo, 2007). A defensive mechanism of the animal against tannins has been found to be salivary proteins (Shimada, 2006).

Comparism of Tannin effects on Fiber Digestibility and Overall Feed Efficiency

Tannins in fodder affect nutritional value in both good and negative ways (Mueller Harvey and Mc Allan, 1992). High amounts of tannins impair animal performance, protein and carbohydrate digestibility, and intake (Reed *et al.,* 1990). Tannins reduce ruminal NH3-N by slowing down the rate of protein deamination and breakdown in the rumen (Woodward, 1989). When sheep and goats were fed tannin-containing legumes, there was a decrease in plasma urea nitrogen, ruminal NH3-N, and urinary N loss (Woodward, 1988). Tannins may improve the urea recycled to the rumen's efficiency. Depending on the chemical structure and concentration of meals, the makeup of the base feed, and other aspects that are inherently related to the animals, including the species and physiological stage, tannins are thought to have both negative and positive effects (Piluzza *et al.,* 2014). Reduced feed intake, nitrogen and fibre digestibility, and animal performance are examples of adverse impacts (Waghorn, 2008). On the other hand, tannins have been shown to reduce the risk of bloat, increase the digestion of protein, suppress internal parasites, and promote milk production and growth performance (Piluzza *et al.,* 2014). Additionally, it is well known that tannins contain antioxidant activity. According to certain research, eating tannins may enhance an animal's antioxidant status (López-Andrés *et al.,* 2013).Studies have indicated that adding plants or plant extracts rich in tannins to ruminant diets increases levels of health-beneficial FA in meat and milk and improves the oxidative stability of meat; however, the potential negative effects of tannins on animal performance and organoleptic properties of products pose a significant barrier to the widespread use of this nutritional strategy. In recent years, there has been a growing interest in using plants and plant extracts rich in tannins for use in nutritional strategies for improving some aspects of the quality of products from ruminants, specifically fatty acids (FA) composition and oxidative stability. Given that an animal's physiological state influences its nutritional requirements, it appears that one of the elements influencing ruminants' reactions to diets containing CT is the animal's physiological status (Waghorn, 2008).

Many experiments have been carried out on animals with higher protein requirements, such as lambs (Ramírez-Restrepo *et al.,* 2005) or lactating ewes and cows (Woodward *et al.,* 2004). These animals can respond to an increase in dietary protein and can therefore perform better in response to an excess of amino acids (Barry and Manley, 1984).The productive response to CT-containing forages is primarily beneficial, with potential improvements in daily gain of 8–38% and milk output of 10–21% as compared to controls (Waghorn, 2008). Increased availability of amino acids, especially branched-chain amino acids, methionine, and lysine, may stimulate the synthesis of milk protein and lactose (via neoglucogenesis) in relation to milk production, thereby augmenting total production (Wang *et al.,* 1996). However, the quantity eaten as well as the general quality of the meal will also have an impact on the performance of the animal. Greater availability of amino acid absorption may result from an intake of less than 50 g CT/kg DM (Min *et al.,* 2003). When combined with a medium-poor quality diet, the consumption of CT from browse has a negative impact on performance (Waghorn, 2008). Bloat is a digestive disease that affects ruminants who graze on legumes that are highly digested fodder, such clove or lucerne. When soluble protein-rich legumes are digested, stable foam may form, which restricts the amount of gas released during eructation during fermentation. The accumulation of gas causes the rumen to expand or stretch. Legumes containing CT, such as Astragalus cicer L., Lotus corniculatus, Coronilla varia, and Onobrychis vicciifolia, have been shown to reduce bloat in ruminants whether fed alone or in combination with forages that cause it (Wang *et al.,* 2012).

METHANE EMISSION

Roles of Tannins in Reducing Methane Production in Ruminants

During the process of reducing enteric methane (CH4) emissions from ruminants, tannins are thought to be a potential class of chemicals. Methane generation in rumen poses both an environmental and financial challenge. Methane is widely recognised as a powerful greenhouse gas, and 28% of all anthropogenic methane is produced by ruminants (Beauchemin *et al.,* 2008). Additionally, according to Lopez and Newbol (2007), the CH4 generated during ruminal fermentation represents a 5-8% loss in gross energy intake. A greenhouse gas known to cause large energy losses in ruminants, enteric methane is projected to contribute 2,079 and 2,344 Mt CO2-eq/year globally in 2010 and 2020, respectively (Hristov *et al.,* 2013). Methanogenic archaea and symbiotic protozoan partnerships create enteric methane during feed fermentation as a means of disposing of metabolic hydrogen (Leng, 2008). Decrease of methane developing a plan that reduces the activity and proliferation of the microbiota that produces methane without impairing rumen function is essential. As per the Bhatta *et al;* (2009) report, tannins are being explored more and more as a potential strategy to lower methane emissions from ruminants. This is because they are thought to be chemicals that show promise in reducing rumen methanogenesis. One of the most important nutritional objectives for ruminants is to reduce methane (CH4) emissions (Ramaiyulis *et al;* 2022). Animal breeding, feed modification, and rumen manipulation are the three categories of methane emission reduction strategies (Arndt et al., 2021). Concentrate and tannin supplementation reduced CH4 Yield (g/kg DMI) by 13.7–17.4% and CH4/Gain by 20.1%, according to a meta-analysis (Congio *et al.,* 2021).

EFFECTS OF TANNIN ON RUMINANTS ANIMAL HEALTH AND WELFARE

The benefits of tannins in terms of lowering intestinal parasites are also linked to their significance in animal diets. Traditionally, anthelmintic medication has been used to control ruminant gastrointestinal parasites. Unfortunately, as a result of growing parasite resistance to popular anthelmintics and the detrimental effects of chemical treatments used in animal agriculture on the environment, animal welfare, and feed safety, this process is getting harder to carry out (Min and Hart, 2003). A direct effect of tannins on nematodes has been demonstrated by feeding studies (Butter *et al.,* 2000), wherein they inhibit eggs and infective larvae and reduce larvae mobility. An indirect effect is also demonstrated by tannins, as they increase protein availability, which fortifies the immune system and increases resistance to infections (Min and Hart, 2003). Using feeds high in tannin has been suggested as an alternative to conventional parasite control methods (Nguyen *et al.,* 2005). This approach has been researched. Due to their impact on internal nematodes in ruminants, plants high in tannin have garnered the greatest interest. It has been utilised to prevent a variety of intestinal parasites in ruminants by using external tannins from plants including mimosa (HT), chestnut (HT), and quebracho (CT) (Min and Hart 2004). One of the suggested substitutes for conventional parasite control methods that has been researched is the use of diets high in tannin (Nguyen *et al.,* 2005). The effect of tannin-rich plants on internal nematodes in ruminants has garnered the greatest attention. Mimosa (HT), chestnut (HT), and quebracho (CT) are examples of external tannins that have been utilised to suppress a variety of intestinal parasites in ruminants (Min and Hart, 2003). According to a summary of in vivo research conducted by Hoste *et al;* (2006), tannins from chicory, sainfoin, sulla, Lotus pedunculatus, Sericea lespedeza, and Acacia nilotica significantly acted as anthelmintics in the digestive tracts of sheep, goats, and deer. Furthermore, Hedychium coronarium, Lotus pedunculatus, Lotus corniculatus, and Onobrychis viciifolia CTs were shown to exhibit anthelmintic-like activity against deer lungworm and gastrointestinal larvae, indicating that these forages may offer an alternate method of managing internal parasites in deer (Molan *et al.,* 2000).

PRACTICAL APPLICATION OF TANNINS

With an estimated 1076.3 kilotons of tannin needed in 2015 and a compound annual growth rate (CAGR) of 5.8% from 2016 to 2025, the global tannin market is growing quite quickly. Specifically, the wood, wine, leather, and pharmaceutical industries were in high demand. Only the leather industries utilise 62.3% of the roughly 282.4 kilotons of tannins that were generated in the USA. Tannings and goods containing tannins are also seeing growth in Europe. The reason for this is that 38% of Europe's revenue is generated by the large-scale wine industry. As a result, the tannin-related industries could have a $3.3 billion global market by 2025. Condensed tannin applications are predicted to reach 424.8 kilotons by 2025, up from 242.9 kilotons in 2015 (Grandview, 2017). However, there are a number of unanswered questions regarding tannin applications, including antinutrient effect, resistance to enzymatic hydrolysis, and incomplete knowledge about interactions with other biomolecules and animal and human modes of action. For both established and developing sectors, tannins may be the ideal natural raw material. Tannin's distinct chemical structure, natural qualities, and commercial qualities are responsible for this (Luckeneder, *et al;* 2016). Tannins have many benefits, including being an effective medicinal, biopesticide, antioxidant, biomaterial, and nutraceutical agent. There have been efforts made to create packing materials from biological sources, such as chitosan, starch, gelatin, tannins, and methylcellulose, and the idea of natural and active packaging has been developed (Kamari and Phillip, 2018). The best choice is active packaging, which not only shields the feed item from oxidation, UV rays, and moisture-based degradation but also serves as an addition to boost the antioxidant qualities of feed and absorb undesirable things like heavy metals or used oils. Packaging films based on chitin now have far better antioxidant and antibacterial qualities because to the addition of tannins. Chitin and tannins form hydrogen and hydrophobic bonds, which is primarily responsible for the improved quality of chitin-based films (Wang *et al.,* 2016). Animal skin is typically turned into leather in the leather industry by the addition of tannins. As stated by Kaygusuz *et al;* (2018), tannins have a major role in shielding leather from deterioration caused by heat and microorganisms.

RESEARCH CHALLENGES AND FUTURE RESEARCH

Aside their biological functions, they hold significant roles in the mining, chemical, tanning, and industrial sectors. They also feed animals. However, there are a few restrictions related to tannins. The primary drawback of tannins as feed is that they bind and absorb many kinds of biomolecules in the digestive tract, including proteins, carbohydrates, and metal ions. This prevents humans and animals from getting the nutrients that some biomolecules, such proanthocyanidins, provide. According to certain studies, the digestive systems of animals contain complexes of tannins and proteins that are resistant to different kinds of proteases, rendering the proteins unfit for feeding livestock. Dietary tannins attach to proline-rich proteins, forming soluble and insoluble complexes that give rise to an astringent feeling (He *et al.,* 2015). Additionally, some studies reveal that tannins also lower the activity of intestinal bacteria, which results in less soluble fibre and organic matter being absorbed and is linked

to harm to the digestive system's mucosal lining. Most tannins utilised in the livestock industry today are either entire plants containing a wide range of secondary chemicals or crude extracts of combinations with varying molecular sizes. Combining this with the differences in the chemical structures and compositions of the compounds from various sources and growth environments would lessen the possibility that microbes would develop a resistance to the complex tannins. Though not much research has been done in this area, the scientific community, regulatory agencies, and the production industry must work together to stop microorganisms from developing resistance to tannins and other plant secondary compounds that are crucial to human health because doing so will have far-reaching effects on all of humanity.

CONCLUSION

The review concluded that tannin play several roles in ruminant nutrition through the complex connection of beneficial and non-beneficial effects. There is need to properly regulate hydrolysable tannin amount included in the ruminant diet to avoid negative impacts on animal health. The inclusion of condensed tannin on the other hand offers a number of advantages which aid protein utilization improvement and reduction of nitrogen excretion thus improving the performance of ruminant animal significantly. The balance incorporation of tannin in animal diet have positive effects which includes better feed efficiency, improved nutrient absorption, bloat prevention, and fight against parasitic infections. There is need to include a required level of tannins in animal diet for better formulation. There is need for researchers to seek for strategic inclusion of tannins to diet especially types and amount to optimize ruminant health and productivity. The need for future studies to continue with more understanding of tannin activities within the rumen and ways to develop protocols for effective consumption is ruminant nutrition is paramount.

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ID: 434

Understanding Molecular Mechanisms: Recent Advancements in Plant Resilience to Drought and Salinity

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Abstract

Plant stress, drought, and salt reduce agricultural output and food security worldwide. Rising cultivable land salinity is expected to reduce land availability by 30% in 25 years and maybe 50% by 2050. Therefore, plant biotechnology initiatives must prioritize drought and salinity stress tolerance in agricultural plants (to assure food security) and forest trees (which are vital to world ecology). Salt and drought stress have a large impact on plant development, photosynthesis, ionic equilibrium, and oxidative balance than each stress alone. CRISPR/Cas9, which stands for clustered regularly interspaced short palindromic repeats, is a new way to edit plant genomes correctly and quickly. The metabolic abilities of several plant growth-promoting microorganisms (PGPM) may reduce the impacts of abiotic stresses. Plant-microbe interaction impacts non-living stress factors, and PGPR (Plant Growth-Promoting Rhizobacteria) such as mycorrhizal fungi and endophytes manage these stresses to enhance agricultural productivity and minimize losses. We also discuss their role in aquaporin water absorption and transport. Drought stress mobilizes plant energy to produce defense components and osmo-protectants like proline, which damages plant development. This review aims more research into plant-microbe interactions and stress tolerance ways at the molecular level. By improving our knowledge in this domain, we can develop innovative solutions to reduce soil salinity and drought stress, ensuring food security and sustainable agriculture in changing climates.,

Keywords: *Abiotic Stress; Drought; Salinity; Plant Biotechnology; Plant Immunity; Botany*

ID: 435

Recent trends developed to modify plant proteins, their effects and applications

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Abstract

Plant protein sources are gaining awareness because of their nutritional enrichment, imminent scarcity of animal proteins, high sustainability, and essential role in the manufacture of functional meals and bioactive peptides. However, negative consequences include the presence of anti-nutritional substances and low digestion may make plant protein sources problematic. Additionally, as compared to animal proteins, plant proteins usually have worse functional qualities and palatability.Many methods are available and are currently being investigated to modify the negative effects of plant proteins. One of these methods is the use of Maillard reactions.In the early phases of the Maillard process, glycosylation is the structural alteration of proteins caused by the addition of polysaccharides, which results in the formation of protein-polysaccharide conjugates. It has been demonstrated that the green and effective process of glycosylation produces changed proteins with improved solubility, emulsifying, and forming capabilities. Another method that can be used is fermentation. The production of bioactive peptides derived from fermentation and their application in commercial products is of significant value. The potential effects of new technologies in plant protein sources such as co-fermentation are being widely investigated. Moreover, many non-thermal approaches have been researched to enhance plant proteins' functional properties without compromising their nutritional value or sensory appeal. The technologies involved include dynamic high-pressure microjets, pulsed electric fields, cold plasma, ultrasound, and high hydrostatic pressure. There is a need to explain in detail the effects of these technique on the functional and structural behavior of proteins and to provide new perspectives.

Key Words: *Plant protein, , Glycosylation, Fermentation, Non-thermal treatments*

ID: 436

Balık ve Yoğurt Tüketiminin Zehirlenme Algısı Açısından Biyojen Aminler Üzerinden Değerlendirilmesi

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Özet

Biyojen aminler, canlı organizmalarda ve gıdalarda doğal olarak bulunabilen serbest aminoasitlerin dekarboksilasyonu sonucu oluşan organik azot bazlarıdır. Gıdalarda bozulmanın bir göstergesi olarak et, balık, peynir, sebze, şarap vb. gibi protein içeriği yüksek veya fermente ürünlerde yaygın olarak bulunmaktadır. Gıdalarda bulunan türleri; histamin, tiramin, putresin, kadaverin, β-feniletilamin, agmatin, triptamin, serotonin, spermidin ve spermindir. Toksisitesi en yüksek biyojen aminler içerisinde histamin ve tiramin bulunmaktadır. Ekzojen enzimlerin aktivitesi sonucu histidin aminoasiti dekarboksile olarak histamine dönüşmektedir. Histamin, yaygın olarak balık ve balıkçılık ürünlerinde bulunmasının yanı sıra yoğurt ve peynir gibi fermente süt ürünlerinde de varlığına rastlanan bir biyojen amindir. Aminoasitlerin varlığına, dekarboksilasyondan sorumlu mikroorganizmaların gelişmesini ve aktivitesini destekleyecek koşullara (pH, sıcaklık, oksijen, su aktivitesi, NaCl konsantrasyonu, katkı maddeleri ve rekabetçi mikroorganizmalar vb.) bağlı olarak histamin birikimi meydana gelmektedir. Yüksek histamin içeriğine sahip *Scombridae* ve *Scomberesocidae* familyalarından (ton balığı, uskumru, palamut, lüfer vb.) balıkların tüketilmesi "Scombroid Zehirlenmesi olarak da bilinen "Histamin Zehirlenmesi" ile ilişkilidir. Amerikan Gıda ve İlaç Dairesi (FDA) tarafından, 100 g balık etinde en fazla 50 mg/kg histamin bulunabileceği rapor edilmiştir. Avrupa Birliği'ne üye ülkeler ve Türkiye'de ise bu miktar 100 mg/kg'dır. Uygun olmayan proses ve depolama koşulları neticesinde histamin içeriği artan ürünlerin tüketimine bağlı olarak gözlemlenen zehirlenmenin yaygın belirtileri; düşük kan basıncı, baş ağrısı, ödem ve alerjik reaksiyonlara özgü döküntüler şeklindedir. Bu çalışma, balık ve yoğurdun birlikte tüketilmesinin "zehirlenmeye" yol açtığına dair yaygın inanışı biyojen aminler açısından değerlendirerek, bu besinlerin kombinasyonunun toksik etki oluşturabilmesi için belirli konsantrasyon eşiklerinin aşılması gerektiğine dair verileri ortaya koymuştur. Elde edilen veriler, balık ve yoğurt kombinasyonunun biyojen amin düzeylerinde kayda değer bir artışa neden olmadığını, ancak belirli saklama koşulları ve bireysel tolerans farklılıklarının semptomların şiddetini etkileyebileceğini göstermektedir. Başta, histamin ve tiramin gibi biyojen aminlerin varlığının, balık ve süt ürünleri tüketimiyle ilişkili semptomların temel nedeni olabileceği ancak gıda güvenliği standartlarına uygun ürünlerin tüketilmesi durumunda riskin minimal olacağı anlaşılmaktadır.

Anahtar Kelimeler: *Histamin, balık, balık-yoğurt, biyojen amin, histamin zehirlenmesi*

ID: 437

Assessment of Consumer Willingness to Consume Artificially-Sweetened Roselle Beverage

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Abstract

The use of artificial sweeteners in developing countries is increasing, however, usage for sweetening indigenous drinks such as roselle beverage (Bissap) is limited. In this study, the objective was to assess the acceptability of artificially sweetened Bissap using either sucralose or saccharin, and evaluate consumers' willingness to consume artificially sweetened Bissap. Sensory evaluation by a 44-member panel, revealed that 52.27 % of consumers preferred sucrose-Bissap compared to sucralose- (31.82 %) and saccharin-Bissap (13.63 %), with the major reason given for the preference of sucrose-Bissap attributed to the dislike of the aftertaste associated with using the artificial sweeteners. The major sensory attributes used to describe sucralose-Bissap cloudy/foamy while saccharin-Bissap was described as been bitter in taste.

Keywords: *Roselle beverage, sucralose, saccharin, sensory evaluation, consumer acceptability*

ID: 438

Ultrasound-assisted Enzymatic Hydrolysis of Safflower Protein Isolate

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Abstract

This study evaluated the effect of ultrasound pretreatment on the physicochemical properties of safflower protein hydrolysate. Safflower protein isolate prepared using alkaline extraction and isoelectric precipitation methods, was hydrolyzed via Alcalase without and with ultrasound pretreatments at 200 W (20 kHz) for 10 and 20 min, and then the degree of hydrolysis, solubility, oil binding capacity, emulsifying and foaming properties of hydrolysates were analayzed. The degree of hydrolysis of the samples was found to be in the range of 13.83-14.08. A slight decrease in the solubility of safflower protein hydrolysate was detected from 90.85% to 87.48% with ultrasound pretreatment. On the other hand, ultrasound pretreatment increased the oil binding capacity and emulsion capacity of safflower protein hydrolysate by up to %17.96 and 18.86%, respectively. However, no stable emulsion structure was observed in ultrasound pretreated hydrolysates. Additionally, the highest foaming capacity and stability values were found in hydrolysate with ultrasound pretreatment for 20 min, which were 130.00% and 49.99%, respectively. The results of this study highlighted the potential of ultrasound pretreatment as an effective method for enhancing the physicochemical properties of safflower protein hydrolysate.

Key Words: *Safflower protein, Ultrasound, Hydrolysis, Emulsifying properties, Foaming properties*

Aspir Protein İzolatının Ultrases Destekli Enzimatik Hidrolizi

Özet

Bu çalışmada, ultrases ön işleminin aspir protein hidrolizatının fizikokimyasal özellikleri üzerindeki etkisi değerlendirilmiştir. Alkali ekstraksiyon ve izoelektrik çöktürme yöntemleri kullanılarak hazırlanan aspir protein izolatı, Alcalase ile ultrases ön işlemi uygulanmadan ve 200 W (20 kHz)'da 10 ve 20 dakika boyunca ultrases ön işlemleri uygulanarak hidrolize edilmiş ve sonra hidrolizatların hidroliz dereceleri, çözünürlükleri, yağ bağlama kapasiteleri, emülsiyon ve köpürme özellikleri analiz edilmiştir. Örneklerin hidroliz derecesinin %13.83-14.08 aralığında olduğu tespit edilmiştir. Ultrases ön işlemiyle, aspir protein hidrolizatının çözünürlüğünde %90.85'ten %87.48 seviyesine kadar hafif bir azalma tespit edilmiştir. Diğer yandan, ultrason ön işlemi aspir protein hidrolizatının yağ bağlama kapasitesinde %17.96'ya kadar, emülsiyon kapasitesini ise %18.86'ya kadar artış sağlamıştır. Ancak ultrases ön işlemine tabi tutulan hidrolizatlarda stabil bir emülsiyon yapısı gözlenmemiştir. Ayrıca, 20 dakika ultrason ön işlemi uygulanan hidrolizat örneğinde en yüksek köpürme kapasitesi ve stabilite değerleri sırasıyla %130.00 ve %49.99 olarak bulunmuştur. Bu çalışmanın sonuçları, ultrases ön işleminin, aspir protein hidrolizatının fizikokimyasal özelliklerini iyileştirmede etkili bir yöntem olarak potansiyelini vurgulamıştır.

Anahtar Kelimeler: *Aspir proteini, Ultrases, Hidroliz, Emülsiyon özellikleri, Köpürme özellikleri*

ID: 440

Farklı Şekillerde Dondurulduktan Sonra Termal Strese Maruz Bırakılan Alabalıkların Kalite Değişimlerinin Makine Öğrenmesi İle Belirlenmesi

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Özet

Bu çalışmada, farklı dondurma yöntemlerine tabi tutulmuş alabalıkların 25 °C'de maruz bırakıldıkları termal stres süresince gerçekleşen kalite değişimleri, makine öğrenmesi ve görüntü işleme teknikleri kullanılarak değerlendirilmiştir. Deneysel tasarımda taze (dondurulmamış), ev tipi dondurulmuş ve endüstriyel (glaze) dondurulmuş olmak üzere üç ayrı grup oluşturulmuştur. Her bir grup için 0–7 saatlik depolama süresince, her saat başında farklı açılardan 175 adet olmak üzere toplamda her sınıftan 1400, genel toplamda ise 4200 görüntü elde edilmiştir. Görüntü kaydı, sabit bir ışık ortamında ve mobil cihaz kullanılarak gerçekleştirilmiş, böylece veri setinde homojenlik sağlanmıştır. Görüntülerin analizinde derin öğrenme modellerinden ResNet-50 mimarisi kullanılarak öznitelik çıkarımı yapılmış, ardından bu öznitelikler destek vektör makineleri (SVM) ile sınıflandırılmıştır. Sınıflandırma performansının eğitim verisi oranıyla doğrudan ilişkili olduğu gözlemlenmiş, eğitim oranı %40'ın üzerine çıktığında üç sınıf için de %90'ın üzerinde doğruluk elde edilmiştir. Elde edilen bulgular, dondurma işlemlerine bağlı olarak meydana gelen tekstürel deformasyonlara rağmen, alabalıkların kalite değişimlerinin makine öğrenmesi yaklaşımları ile başarılı bir şekilde tespit edilebileceğini göstermektedir.

Anahtar Kelimeler: *Alabalık, Termal stres, Makine öğrenmesi, Sınıflandırma, ResNet-50*

ID: 441

The some quality traits of oriental mustard lines in Ankara conditions

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Abstract

The environmental impacts of fossil fuel use make research and development studies for sustainable alternative solutions from renewable sources important. Thuse, there is a need to determine inexhaustible, renewable and sustainable biodiesel resources for biodiesel production from fixed oils obtained from plant sources. Oriental mustard is a species that contains a significant amount of fixed oil in its seeds. This study was carried out in 2020 in Ankara, Türkiye, in order to determine and compare some quality traits of five oriental mustard purelines in autumn sowing conditions under continental climate conditions. Oriental mustard lines used in this study were get from USDA gene bank and bred by pure line selection method. Field studies were carried out according to randomized block design with four replications. According to the results, it was shown that all oriental mustard purelines were statistically significant for moisture percentage in seed, crude oil percentage in moist seed, crude oil percentage in dried seed, palmitic, stearic, oleic, linoleic, linolenic, eicosenoic and erucic acids. Erucic acid (20.01-24.41%), oleic acid (21.60-24.23%) and linoleic acid (20.11-22.24%) were determined as the main fatty acids. Fixed oil ratio of purelines varied between 27.83 and 42.10%. The results determined showed the potential of using in future breeding programs for alternative medicine, paint, food and biodiesel industry. It is thought that the crude oil content of Bjo3, Bjo4 and Bjo5 stages is quite high and can be evaluated in variety breeding studies for a more economical production in the supply of raw materials to different industries.

Key Words: *Brassica juncea, Crude oil ratio, Fatty acid component*

Introduction

The increasing energy demand due to the effects of increasing population, industrialization and urbanization has caused the negative effects of fossil fuels on the environment to increase (Nayak et al., 2019). Sustainable and renewable biodiesel raw materials are attracting attention in order to secure future energy demands. Oilseed crops, animal oils and cooking oil wastes are used as biodiesel raw materials (Gómez-Trejo-López et al., 2022; Ishak et al., 2022). Oils with high erucic acid percentage obtained from different *Brassica* species are not appropriate for people utilization because of their possible harm to human health (Poddar et al., 2022) and are considered inedible oils. Inedible oils can be used as potential low-cost sources for biodiesel production due to their high erucic acid percentage (30-40%) (Yeşilyurt et al., 2019; Kayaçetin and Khawar, 2023).

Brown mustard is an amphidiploid species that was formed in nature by crossbreeding diploid species (*B. nigra* and *B. rapa*) through different factors (Malek et al. 2012). This species has two types of seed color, brown and yellow (oriental), has a one-year vegetation period and is a multi-branched plant originating from South and East Asia (Rahman et al., 2018; Kayaçetin, 2020). It is thought that this species originally existed in East India, the Caucasus, and China, and later spread to Europe, Africa, North America, and Asia (Szőllősi, 2020).

Although they contain different compounds such as glycosides, arachidic acid, sinabine, lignoceric acid, erucic acid in their oils, and these types with high erucic acid are not suitable for direct food use, they are used for different purposes in the spice, pharmaceutical and cosmetic industries, green manure, soil remediation, biofuel raw material, beekeeping, animal feed and different industrial branches (Tonguç and Erbaş, 2012; Rahman et al., 2018; Kayaçetin, 2020; Kayaçetin and Khawar, 2023). The above-ground organs of the plant are used for medical, food, feed and industrial purposes (Divakaran and Babu, 2015; Kayaçetin, 2020; Aslan, 2023;).

Oriental mustard (*Brassicaceae* family), is among the most economically significant oilseed crops (Rahman et al., 2018). The oils extracted from this crops serve as valuable sources of edible oil, biofuel, and industrial feedstocks (Sachan et al., 2024). Moreover, they contribute significantly to global agriculture and food-energy security due to their adaptability to diverse agro-climatic conditions and high oil yields per unit area (Kayaçetin, 2023). The fixed fatty acid components such as oleic acid, erucic acid and linoleic acid determine the suitability of oil for industrial or food use (Sachan et al., 2024).

This research was carried out in 2020 in Ankara, Türkiye, in order to detect and compare some quality traits of five purelines in autumn sowing under continental climate conditions.

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Materials and Methods

Five oriental mustard lines obtained from the USDA gene bank and characterized by the Field Crops Central Research Institute, Ankara, Turkey were used in the study.

Field trials were carried out in Ankara in the experimental area of the Institute in the autumn growing season of 2019-2020 and 925 m above sea level, based on the randomized block design with four replications. Oriental mustard seeds were sown on September 15, 2019, in 6-row plots with 30 cm row spacing and 6 m length, with 200 plants per m^2 in autumn sowing. It was harvested on July 1, 2020 during the ripening period.

The soils where field studies are carried out have a very low amount of organic matter and are slightly alkaline, and have a clayey loam texture. When the climate data were evaluated; the average total precipitation for long years and the trial year was 391.9 mm and 269.6 mm. The max. and min. temperatures for long years and the trial year were 40.4 °C, –17.9 °C, and 35.5 °C, –12.2 °C, in the same order (Table 1).

Table 1. Monthly meteorological data of oriental mustard of vegetation period (September to August)

Climatic factors	Years/Months	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Agu
Rainfall (mm)	Long years	18	27,7	31,5	44,9	40,2	35,1	39,1	42,5	51,5	34,4	14,3	12,7
	2019-20	1,2	2,2	31	51,4	31	59,4	4,2	0	26,4	59,4	3,4	0
Max. Temp. (ºC)	Long years	37,7	28,5	23,1	15,5	12,5	19	23,1	28	29,7	35	36	40,4
	2019-20	29,4	27,2	20,7	10,6	7,2	10,2	19,5	20	30,4	30,5	35,4	35,5
Min. Temp. (ºC)	Long years	-1,5	-6	-11	-14,2	-17,5	-17,9	-13,8	-8	-1,5	3,5	6,3	5,5
	2019-20	1,6	1,9	-5,8	-11,1	-10,1	-12,2	-8,6	-1,7	-1	4,4	14,5	12,2

The crude oil ratio and oil profile analyses of oriental mustard purelines were performed in 4 replications at the DB Agricultural Energy Biofuel Laboratory. The fatty acid profile of lines oil in relation to TS 4664 and EN ISO 5508 was determined by gas chromatography-GC (Kayaçetin, 2023).

Data on seed crude oil percentage and fatty acid profiles of oriental mustard purelines were analyzed using Statistical Analysis Software JMP®13.2.1 using analysis of variance (ANOVA). Differences among means were separated using LSD tests ($p<0.05$).

Results and Discussion

The oil percentage and fatty acid components of oriental mustard pure lines were investigated in this study. Statistically significant variations were determined in terms of the investigated features including moisture percentage in seed, crude oil percentage in moist seed, crude oil percentage in dried seed, palmitic, stearic, oleic, linoleic, linolenic, eicosenoic, erucic acids (Table 2).

The maximum and minimum moisture percentage in seed of 6.09% and 4.64% was detected in Bjo1 and Bjo4, respectively. The maximum crude oil percentage in moist seed (42,10%) and in dried seed (43,76%) were detected in Bjo4 whereas the minimum crude oil percentage in moist seed (27,83%) and in dried seed (29.68%) were detected in Bjo2, in the same as. While the maximum palmitic (3.13%), stearic (1.51%), oleic (24.23%), linoleic (22.24%), linolenic (12.88%), eicosenoic (14.27%), erucic (27.41%) acids were detected in Bjo4, Bjo1, Bjo2, Bjo1, Bjo3, Bjo2, and Bjo5, the minimum palmitic (2.85%), stearic (1.28%), oleic (21.60%), linoleic (20.11%), linolenic (10.35%), eicosenoic (12.01%), erucic (20.01%) acids were detected in Bjo5, Bjo2, Bjo4, Bjo3, Bjo5, Bjo5, and Bjo1, respectively. The differences among the examined traits are thought to be due to genotypes (Table 2).

Table 2. The varied examined traits of oriental mustard purelines

	Moisture percentage in seed (%)	Crude oil percentage in moist seed (%)	Crude oil percentage in dried seed (%)	Palmitic (C 16:0)	Stearic (C 18:0)	Oleic (C 18:1)	Linoleic (C 18:2)	Linolenic (C 18:3)	Eicosenoic (C 20:1)	Erucic (C 22:1)
Russian Federation pureline (Bjo1)	6,09a	29,87c	31,88d	3,11a	1,51a	23,93a	22,24a	12,53a	13,73ab	20,01c
United States pureline (Bjo2)	5,53ab	27,83d	29,68e	3,06a	1,28d	24,23a	20,98b	12,46a	14,27a	21,33c
India pureline (Bjo3)	5,29b	35,81b	37,80b	3,05a	1,37b	21,76bc	20,11b	12,88a	13,21b	24,39b
Canada pureline (Bjo4)	4,64c	42,10a	43,76a	3,13a	1,33c	21,60c	20,59b	12,69a	13,91a	24,27b
China pureline (Bjo5)	5,08bc	34,11b	35,81c	2,85b	1,41b	23,03ab	20,19b	10,35b	12,01c	27,41a
Source of variation (%)	6,48	3,66	3,66	3,19	2,11	3,70	3,65	3,52	2,97	5,57
LSD (0.05) = 2.13 (20 df)	**	**	**	**	**	**	**	**	**	**

Various research articles have reported that the fatty acid profile of oriental mustard genotypes/lines/varieties depending on the genotypes and that the fatty acid profile of this species is rich in monounsaturated fatty acids such as oleic, erucic and eicosenoic and polyunsaturated fatty acids such as linolic and linolenic. (Sharafi et al., 2015; Kayaçetin et al., 2018; Rai et al., 2018; Alpaslan, 2019; Shyam et al., 2022; Kayaçetin., 2023; Sachan et al., 2024).

For sustainable biofuel production, obtaining raw materials from plants that cannot be used in food is very important in order not to increase Türkiye's existing crude oil and oilseed deficit (Başalma et al., 2025). Although it is not possible to use the seed oil directly in food due to its high erucic acid content, the fact that oriental mustard contains rich monounsaturated fatty acids such as oleic, erucic and eicosenoic in its crude fatty acid content shows that it can be used appropriately for industrial purposes (Kayaçetin, 2023).

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Assessing the Contribution of *Musa Species* to Sustainable Livelihoods of Agroforestry Farmers in Egbeda Municipality, Oyo State, Nigeria

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ABSTRACT

The livelihoods of agroforestry farmers are compromised by suboptimal management practices, inputs supply constraints, and post-harvest losses. The study assesses the role of *Musa species* in enhancing the livelihoods of agroforestry farmers in Egbeda municipality, Oyo State. A Multistage sampling design was adopted to select a sample size of 95 respondents from four wards. Questionnaire survey was conducted to gather data on socio-economic characteristics, *Musa species* acquisition, availability, management, and livelihood contributions. Data were analysed with descriptive and inferential statistics. Findings revealed that most respondents were males (69.5%), aged 40-50 (30.5%), and married (54.7%). Suckers were primarily sourced from fellow farmers (64.2%). Significant proportion of respondents (77.9%). Chi square analysis revealed significant associations between farmers' age, livelihood activities, and *Musa species*' contribution to livelihood improvement. The study concludes that *Musa species* production enhances agroforestry farmers' livelihoods and recommends training in value-chain production techniques to optimize returns on investments.

Keywords: *Contribution, Musa species, Management, Livelihood enhancement, Optimal yield*

INTRODUCTION

Musa species (Bananas and plantain) occupy a critical position for boosting Nigeria's food production capacity (Akinyemi *et al*., 2010). *Musa species* ranks third among starchy staples with Nigeria's production doubling over the past 20 years. Production is predominantly carried out in Southern Nigeria where smallholder farmers traditionally integrated it into diverse cropping systems. Musa species production sector in Nigeria is characterized by a gender-based division of labour, with men dominating production, and women handling marketing. However, the sector faces challenges, including farmers' limited knowledge of best practices, inadequate extension services, and research specialization biases, which collectively contribution to the country's low yields. Notwithstanding, in recent years, plantain and banana have become increasingly important contributors to revenues of Nigeria's major producing communities. The African continent is the largest producer of *Musa species*, contributing more than 50% to worldwide production (Adeniji and Tenkouano, 2008). Nigeria is one of the largest plantain and banana producing countries in the world (FAO, 2004). West and Central Africa are the dominant producers of Musa species, accounting for 61% and 21% of global production respectively (FAO, 2006). In these regions, approximately 70 million people rely on plantains and bananas for over 25% of their carbohydrate intake, making them a primary source of food energy in the African zone (Ayanwale, 2016). Notably, Nigeria ranks among the world top plantain and banana producers (FAO, 2004). Nigeria's Southern States with forest soils, including Akwa-Ibom, Cross-River, Imo, Enugu, Rivers, Edo, Delta, Lagos, Ogun, Osun, and Oyo states, are the primary regions for Musa species' production (Akinyemi *et al*., 2010). Musa species is produced in these states, and moved through marketing channels to different parts of Nigeria. Its demand is very high with supply competing with its demand, and this has created serious competition on the crop serving the status of earning foreign exchange for Nigeria. Plantain and banana are vital crops in Nigeria serving as a staple food, raw material for various product and a significant source of revenue for many individuals and industries. As a strategic crop in food production, it provides carbohydrates for over 50 million people. Its short gestation period and perennial nature make it an ideal crop. In particular, the unripe, the ripe, and the overripe are utilized in various forms, including being peeled, dried, and processed into flour, it can also be boiled or roasted as food or made into chips while overripe are used industrially serves as a base ingredient in the manufacture of baby food products, biscuits and others products (Akinyemi *et al*., 2010). Consequently, it helps alleviate hunger and food insecurity, and also enhance smallholder farmers to earn more cash and to possess cash at hand during the sales of bananas (Tenkouano *et al*., 2019). However, the main limitation affecting the supply of Musa species is post-harvest losses among others. Bautista and Esguerra (2007) reposed that poor handling and sorting have resulted in postharvest disease and losses. Additionally, certain factors like temperature, relative humidity, atmospheric composition contribute deterioration and destruction of the shelf-life of plantains and bananas. Udosen (2016) ascertained that limited processing capacity are responsible for product wastage over time. Hence, this paper assessed contribution of *Musa species*' production to livelihood enhancement of agroforestry farmers. The objectives for the study were examining the

socio-economic profiles, identifying sources of *Musa species*, identifying *Musa species* availability for production, examining management practices, and assessing the contribution of *Musa species* production to sustainable livelihoods of respondents. Hypotheses testing include relationship between socioeconomic profiles and contribution to sustainable livelihoods of farmers, and relationship between *Musa species*' production and contribution to sustainable livelihoods of farmers.

METHODOLOGY

Study Area

The study was carried out in Egbeda Municipality. The site of study is geographically located on longitude 30˚56'54.753"E, 40˚8'58.585"E, and latitude 70˚27'23.532"N, 70˚18'34.578"N with shared boundaries of Ona Ara Municipality, Lagelu Municipality, North East Municipality respectively in Oyo State, and Irewolede Municipality in Osun State (Tomori, 2012). The municipality is occupying a land mass of 420.75 km². The study area is rainforest vegetation with a certain part being a derived savannah. The local government area comprises 11 wards which are Erunmu, Ebgeda, Owobale, Olodo 1, Olodo 2, Monatan, Olode, Alugbo, Olubadan Estate, Kasumu, and Ayede (Tomori, 2012). The population of the area consists of commercial and smallholder farmers.

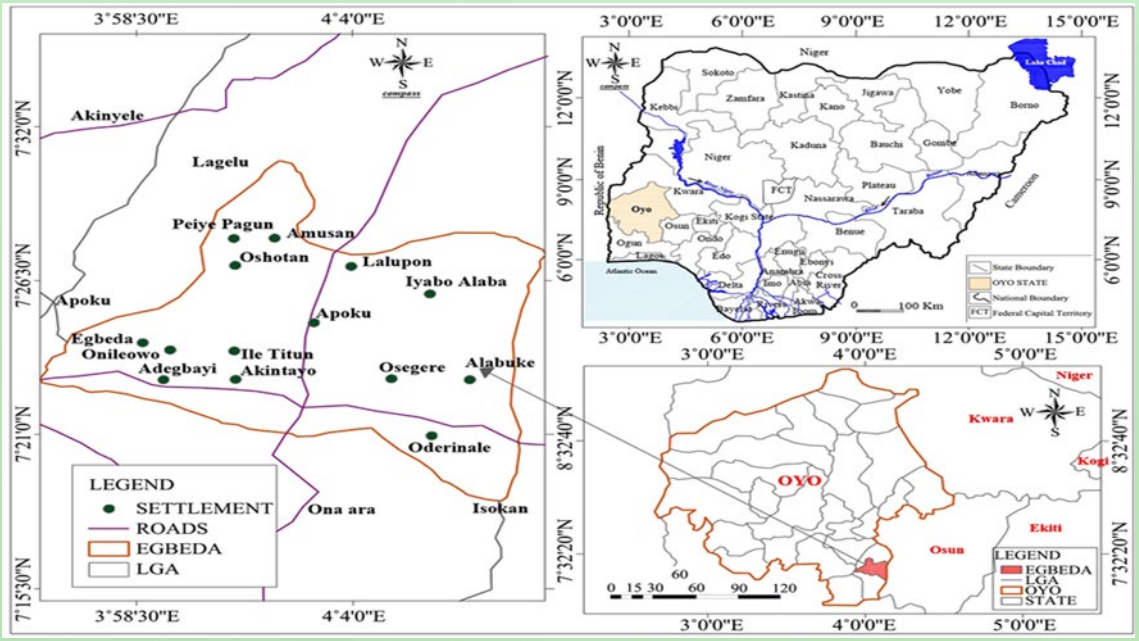


Figure 1. Maps of the Study area (Egbeda Municipality) extrapolated from the map of Nigeria

Sampling Method and Data Collection

The study adopted multistage sampling design. In 1st stage, Egbeda Municipality was purposively selected due to the large number of population of farmers practicing agroforestry. Also, in 2nd stage, 30% of 11 wards from the municipality was selected randomly. Hence, three wards were selected for the study and they were Erunmu, Egbeda, and Ayede. The sample size was selected from these three wards and communities with a random selection of 95 agroforestry farmers. Furthermore, a questionnaire was used to collect data from 95 respondents. The data collected were analyzed using frequencies, simple percentages, and inferential statistical analytical tools like chi-square and PPMC to examine the relationship that exists between the research variables.

RESULTS AND DISCUSSION

Results in Table 1 show that most respondents (69.5%) were males. This indicates male respondents engage more in the cultivation of *Musa species*. This finding corroborates submission of Ayanwale *et al*. (2018) that plantain and banana production was mainly dominated by men who were monogamously married. Majority of respondents (30.5%) that engaged in banana propagation were within age range of 41 to 50 years. This indicates that farmers who engage in production of bananas and plantains were middle-aged men. This result aligns with submission of Ayanwale *et al*. (2018) that the mean age of farmers that engaged in bananas and plantains production were in their midlife. Most respondents (54.7%) were married. This is an indication that marriage infers commitment and responsibility which influence banana production. The result negates the findings of Faturoti *et al*. (2009) who reports singles predominantly engaged in production of *Musa species*. Majority of respondents (82.1%) were having a household size of 5 persons. This indicates that family size could contributes to the robustness of bananas

and plantains production. Also, most respondents (44.2%) engaged in crop farming as one of the other livelihood activities in the study. This indicates that crop farming was another livelihood activity of the agroforestry farmers that enhances production of Musa species. This result corroborates Dimelu (2015) that most household farmers involved in mixed cropping were producers of plantain and banana in Nigeria. In addition, about 50.0% of the respondents had banana and plantain farms ranging from 1 to 2 acres. This implies that the predominant and robust production of *Musa species*. This result agrees with submission of Ayanwale *et al*. (2018) that most household farmers' farm size was less than 1 hectare. Also, 37.8% of respondents had an annual yield of 50 -60 tons of *Musa species*. This indicates that *Musa species* production is a lucrative business. This finding aligns with Nelson *et al*. (2006) who submitted that yield can be as high as 44,092 – 66.139 tons of banana and plantain annually in commercial agroforestry farms orchards. Furthermore, about 44.0% of the respondents had an annual income ranging from ₦501,010 to ₦1,500,000. This is an indication that Musa species production among agroforestry farmers contributed to their annual income. This finding aligns with the submission of Ajibade *et al*. (2022) that the net annual income from sales of *Musa species* was ₦1,907,000.

Table 1: Socio-Economic Characteristics of Respondents

Variable	Frequencies	Percentages
Gender		
Male	66	69.5
Female	29	30.5
Age		
21-30	19	20.0
31-40	25	26.3
41-50	29	30.5
>50	22	23.2
Marital status		
Single	16	16.8
Married	52	54.7
Divorced	13	13.7
Widow (er)	14	14.8
Household size		
1-5	78	82.1
6-10	13	13.7
>10	4	4.2
Other livelihood activities		
Crop farming	42	44.2
Livestock farming	23	24.2
Marketing	30	31.6
Farm size (acres)		
≤ 2	47	49.5
3-4	44	46.3
>5	4	4.2
Yield per annum (tons)		
≤50	30	31.6
50- 60	36	37.8
70-80	22	23.2
> 80	7	7.4
Income per annum (₦,000,000)		
<500,000	30	31.6
501,010-1,500,000	42	44.2
1,510,000-3,000,000	18	18.9
>3,000,000	5	5.3

Table 2: Sources of *Musa species* (Banana and Plantain)

Variable	Frequency	Percentage
Fellow farmers	61	64.2
Research Institutes	27	28.4
Ministry of Agriculture	4	4.2
Private horticultural farms	3	3.2

Results in Table 2 reveal that majority of the respondents (64.2%) were able to source for the suckers of *Musa species* from their fellow farmers. This result indicates that most agroforestry farmers got their planting material from their fellow farmers very close to them. This result corroborates Adeoye *et al*. (2013) who submits that about 92% of farmers sourced their planting suckers directly from their fellow farmers.

Results in Table 3 show that most respondents (60.0%) stated that *Musa accuminata* was available and 67.4% of respondents also stated *Musa balbisiana* too was available. This finding indicates that *Musa accuminata and Musa balbisiana* were predominantly available for production among farmers. This finding concurs with Adewole (2017) that *Musa species* of different varieties were predominantly available in southwest Nigeria as one of the staple foods.

Results in Table 4 show that most respondents (71.6%) agreed that seasons do not affect the production of bananas and plantain. This indicates that cultivation of *Musa species* thrives during rainy and dry seasons due to its perennial nature. This result concurs with Sense (2016) that *Musa species* need both hot and humid environments with an average temperature of 30°C and rainfall well distributed throughout the year. Furthermore, majority of the respondents (81.1%) propagated bananas with suckers sourced from their fellow farmers. This implies that banana and plantain suckers were sourced from fellow farmers which ease the stress of sourcing planting materials for robust production of banana and plantain. This result corroborates Agbongiarhuoyi *et al*. (2016) that majority of farmers sourced their planting materials from their fellow farmers. About 57.0% of respondents applied inorganic fertilizers on their farms. This indicates that applying fertilizer is important to value addition for a robust production of banana and plantain. This finding aligns with the submission by Norgrove and Hauser (2014) that majority of smallholder farmers involved in the cultivation of plantain applied fertilizer as a cultural practice. Also, most respondents (76.8%) stated that the length of maturity of bananas ranges from 9 months to more months. This indicates that the duration of banana and plantain production takes up to 9 months or more. This result conforms to the opinion of Agu (2018) that farmers need 8-9 months to harvest fully mature fruits of plantain and banana.

Results in Table 5 show that about 63.0% of respondents signified more sources of income from the production of bananas and plantain, and about 78.0% of respondents established that there was increase in their income from banana and plantain sales after harvest. Furthermore, the majority of the respondents (92.6%) had improved living standards. This indicated that banana and plantain production was a lucrative business among the agroforestry farmers which was evident in its contribution to their livelihood enhancement in the study area. This result corroborates Akinyemi *et al*. (2010) that the production of *Musa species* production has tremendously raised the income of rural livelihoods.

Table **3: *Musa species* Available for Production among Agroforestry Farmers**

Variable	Yes	No
	Frequency (%)	Frequency (%)
Musa accuminata (Wild Banana)	57 (60.0)	38 (40.0)
Musa balbisiana (Plantain)	64 (67.4)	31 (32.6)
Musa baradisiaca (Hybrid Banana)	28 (29.5)	67(70.5)

Percentages in parentheses

Table 4: Production Practices in Cultivation of *Musa Species* by Agroforestry Farmers

Variable	Yes	No
	Frequency (%)	Frequency (%)
Seasons do not affect the production of *Musa species*	68(71.6)	27(28.4)
Use of suckers from tissue culture for propagation	22(23.2)	73(76.8)
Use of suckers from fellow farmers for planting	77(81.1)	18(18.9)
Spacing of suckers during planting is essential	65(68.4)	30(31.6)
The application of inorganic fertilizer is very important	54(56.8)	41(43.2)
Use of agrochemicals important for production	17(17.9)	78(82.1)
Length of maturity between 9 months and 11 months	73(76.8)	22(23.2)
Some species mature in 12 months or more	28(29.5)	67(70.5)

Percentages in parentheses

Table 5: Contribution of *Musa Species* Production to Sustainable Livelihoods of Agroforestry Farmers

Variable	Yes	No
	Frequency (%)	Frequency (%)
Increase in sources of income	60(63.2)	35(36.8)
Improvement of income after sales	74(77.9)	21(22.1)
Improvement in standard of living	88(92.6)	7(7.4)
Contribution to food security	49(51.6)	46(48.4)

Percentage in parentheses

Table 6: Relationship between respondents' socio-economic characteristics and contribution of *Musa species* production to sustainable livelihoods of agroforestry farmers

Variable	χ^2	p-value	Decision
Sex	2.85	0.09	Not significant
Age	8.78	0.03	Significant
Marital status	6.48	0.09	Not significant
Household size	2.17	0.34	Not significant
Other livelihood activities	13.30	$1x10^{-3}$	Significant

Note: χ^2 = Chi-square coefficient, p = level of significant @ $\alpha_{0.05}$

Table 7: Relationship between the production of banana species and contribution of *Musa species* production to sustainable livelihoods of agroforestry farmers

Variable	r-value	p-value	Decision
Musa production and Sustainable livelihoods	-0.026	0.04	Significant

Note: r = correlation coefficient, p = level of significance @ $\alpha_{0.05}$

The results in Table 6 reveal that age (χ^2= 8.78, p<0.05), and livelihood activities (χ^2= 13.30, p<0.05) of the respondents are significantly related to the contribution of *Musa species* production to sustainable livelihoods of agroforestry farmers. This result implies that the age of farmers and their other livelihood activities have a high level of dependency on the contribution of *Musa species* production to the farmers' livelihood enhancement. This indicated that the farmers' age and other livelihood activities were germane factors of years of experience and practice *Musa species* production that contributed to the livelihood enhancement of the agroforestry farmers. This result corroborates Kainga *et al*. (2014) that the average age of *Musa species* farmers was approximately 45 years and their other livelihoods mean to contribute to livelihood improvement.

The result in Table 7 showcased a weak correlation but significant relationship between the production of banana species and contribution of *Musa species* production to sustainable livelihoods of agroforestry farmers (r =- 0.026, p = 0.04). This result implies that respondents' production of practices had an influence on the livelihood enhancement of the farmers indicating production practices are favorable and impactful on the livelihood enhancement of the agroforestry farmers. This finding concurs with submission of Sengar *et al*. (2019) that the management practices involved in the production *of Musa species* raise the yield of banana and plantain thereby enhancing income and sustaining the livelihoods of farmers.

CONCLUSION

The study assessed contribution of *Musa species* to sustainable livelihoods of agroforestry farmers in Egbeda municipality, Oyo State, Nigeria. The findings showed majority of the farmers engaging in *Musa species* production being middle-aged men. These were married people practicing crop farming as an additional livelihood on acres of land for production of *Musa species*. Furthermore, the findings showed that most agroforestry farmers got their planting material from their fellow farmers. The findings also revealed that *Musa accuminata and Musa balbisiana* were predominantly available for production by agroforestry farmers. Several management practices were used to ensure optimum yield for most respondents with an annual yield of 50 - 60 tons of Musa species accruing from their production with an annual income of ranging from ₦501,010 to ₦1,500,000, showcasing a lucrative business with improved income and enhanced living standards. The study recommends an introduction of effective extension services to rural agroforestry farmers by subject matter specialists to meet their information and input needs. In addition, subject matter specialists should train the agroforestry farmers on new techniques of cultivation, and also introduce them to sources of credits and loans that would create a value-chain production and high rate of return on investment.

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Evaluation of the Inhibitory Effect of *Heracleum platytaenium* Boiss Essential Oil Against *Alternaria alternata*

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Abstract

This study aims to evaluate the antifungal effect of the essential oil of Heracleum platytaenium, an endemic plant of Turkey, against the phytopathogenic fungus *Alternaria alternata*. Fungus is a widespread fungal pathogen that causes significant economic losses in agricultural production. Due to the adverse environmental and health effects of chemical fungicides, the search for natural antifungal agents has gained increasing importance.
The antifungal activity of *H. platytaenium* essential oil obtained in different years was tested under in vitro conditions. The essential oils were applied at different concentrations (5, 10, and 20 µL) and examined for their effects on *A. alternata* mycelial growth on Potato Dextrose Agar (PDA) medium. The findings revealed that the essential oil inhibited fungal growth in a dose-dependent manner. The highest inhibition rate was observed at a 20 µL concentration, with the 2021 essential oil achieving up to 86.6% inhibition. These results suggest that the antifungal activity of the essential oil may vary depending on the extraction year.
In conclusion, the essential oil of *H. platytaenium* appears to be a promising natural antifungal agent against *A. alternata*. However, further studies are needed to explore its chemical composition, mode of action, and efficacy against different pathogens. Future research should focus on its potential use as a biofungicide in agricultural production.

Key Words:*Heracleum platytaenium, Essential oil, Antifungal activity, Alternaria alternata*

Heracleum platytaenium Boiss. Uçucu Yağının *Alternaria alternata*'ya Karşı Antifungal Aktivitesi

Özet

Çalışma, Türkiye'nin endemik bitkileri arasında yer alan olan *Heracleum platytaenium* uçucu yağının *Alternaria alternata* adlı fitopatojen fungus üzerindeki antifungal etkisini değerlendirmeyi amaçlamaktadır. *A. alternata*, tarımsal üretimde önemli ekonomik kayıplara yol açan yaygın bir fungal patojendir. Kimyasal fungisitlerin çevreye ve insan sağlığına olumsuz etkileri nedeniyle, doğal antifungal ajanların araştırılması giderek önem kazanmaktadır. Araştırmada, farklı yıllarda elde edilen *H. platytaenium* türünün meyveuçucu yağlarının antifungal etkinliği in vitro koşullarda test edilmiştir. Farklı konsantrasyonlarda (5, 10 ve 20 µL) uygulanan uçucu yağlar, Patates Dekstroz Agar (PDA) ortamında *A. alternata*'nın miselyal gelişimi üzerindeki etkileri açısından incelenmiştir. Bulgular, uçucu yağın doza bağlı olarak fungal gelişimi baskıladığını göstermiştir. En yüksek inhibisyon oranı 20 µL konsantrasyonunda gözlemlenmiş olup, 2021 yılına ait uçucu yağ %86,6'ya varan inhibisyon sağlamıştır. Bu sonuçlar, uçucu yağın antifungal aktivitesinin ekstraksiyon yılına bağlı olarak değişebileceğini ortaya koymuştur. Sonuç olarak, *H. platytaenium* uçucu yağı, *A. alternata*'ya karşı umut vadeden bir doğal antifungal ajan olarak değerlendirilebilir. Ancak, bileşen profili, etkinlik mekanizmaları ve farklı patojenlere karşı geniş kapsamlı testler ile desteklenmesi gerekmektedir. Gelecekteki araştırmalar, tarımsal üretimde biyofungisit olarak kullanımı için daha kapsamlı incelemeleri içermelidir.

Anahtar Kelimeler:*Heracleum platytaenium, Esansiyel yağ, Antifungal aktivite, Alternaria alternata*

Giriş

Bitki hastalıkları, tarımsal üretimde önemli ekonomik kayıplara neden olan başlıca faktörlerden biridir. Sentetik fungisitlerin yaygın kullanımı, çevre ve insan sağlığı üzerindeki olumsuz etkileri nedeniyle giderek daha fazla endişe yaratmaktadır (Damalas ve Eleftherohorinos, 2011). Bu bağlamda, doğal ve çevre dostu alternatifler bulmak, sürdürülebilir tarım uygulamaları için kritik öneme sahiptir. Son yıllarda, bitki kökenli bileşiklerin antifungal özellikleri üzerine yapılan araştırmalar, umut verici sonuçlar ortaya koymaktadır (Firuzi ve ark., 2010).

Heracleum cinsi, Apiaceae familyasına ait olup, dünya genelinde yaklaşık 125 türü içermektedir (Pimenov ve Leonov, 2004). Bu cinsin üyeleri, geleneksel tıpta (antioksidan) ve gıda endüstrisinde kullanımlarının yanı sıra, antimikrobiyal özellikleri nedeniyle de dikkat çekmektedir (Bahadori ve ark., 2016).
Bir çalışmada, Heracleum türlerine ait meyvelerden elde edilen uçucu yağlar GC ve GC/MS ile analiz edilmiştir. Ana bileşen oktil asetat olup, *H. platytaenium* yağında ayrıca oktil bütirat da belirlenmiştir. Uçucu yağlar *Candida glabrata*'ya karşı güçlü antikandidal etki göstermiştir (Iscan ve ark., 2004). Heracleum platytaenium, Türkiye'nin endemik türlerinden biri olarak, fitopatoloji alanında potansiyel bir kaynak olarak öne çıkmaktadır (Akcin ve ark., 2013). *H. platytaenium*'un kimyasal kompozisyonu ve biyolojik aktivitesi çeşitli araştırmaların çalışma konusu olmuştur. Kılıç ve ark. (2016), *H. platytaenium* kök uçucu yağının 70 bileşenden oluşmakta olduğunu ve ana bileşenler p-simen (%33,9), terpinolen (%14,3), γ-terpinen (%7,1), elemisin (%3,1) ve miristisin (%2,9) olarak belirlendiğini rapor etmiştir.
Bitki patojenleri, tarımsal ürünlerde önemli verim kayıplarına neden olmaktadır (Strange ve Scott, 2005). *Alternaria alternata* gibi yaygın fungal patojenler, çeşitli bitki türlerini etkileyerek ciddi ekonomik zararlara yol açmaktadır (Thomma, 2003). *H. platytaenium*'un antifungal özellikleri, bu tür patojenlere karşı doğal bir kontrol ajanı olarak kullanılma potansiyelini düşündürmektedir. Mevcut literatür, *H. platytaenium*'un fitopatolojideki potansiyel kullanımına dair umut verici işaretler sunmaktadır. Ancak, bu alanda daha fazla araştırmaya ihtiyaç vardır ve bitki patojeni funguslarla ilişkili çalışmalar eksik ve yetersizdir. Özellikle, bitkinin spesifik bitki patojenleri üzerindeki etkilerinin detaylı olarak incelenmesi, uçucu yağın aktif bileşenlerinin belirlenmesi ve in vivo koşullarda etkinliğinin değerlendirilmesi gerekmektedir (Isman, 2000; Bakkali ve ark., 2008).
Bu araştırma, *H. platytaenium*'un farklı yıllarda elde ekstrakte edilen uçucu yağların zirai üretimde ekonomik kayıplara yol açan *A. alternata*'ya karşı fitopatolojideki potansiyel kullanımını ele almayı, araştırma boşluklarını belirlemeyi ve gelecekteki çalışmalar için yön göstermeyi amaçlamaktadır. Bitkinin antifungal özelliklerinin daha iyi anlaşılması, sürdürülebilir tarım uygulamalarına katkıda bulunabilir ve yeni, çevre dostu bitki koruma stratejilerinin geliştirilmesine öncülük edebilir.

Materyal ve Yöntem

Uçucu Yağ ve Test Fungusu

Bu çalışmada kullanılan *H. platytaenium* bitkisinin uçucu yağı Isparta Uygulamalı Bilimler Üniversitesi, Ziraat Fakültesi Deneme alanlarında yetiştirilmiştir. Türün 100 gr meyveleri öğütüldükten sonra 3 saat boyunca hidrodistilasyona tabi tutulmuştur. temin edilmiştir. Araştırmada test edilen *Alternaria alterna* Bingöl Üniversitesi Ziraat Fakültesi Fitopatoloji Laboratuvarı'ndaki fungus koleksiyonundan elde edilmiştir.

Besiyeri Hazırlığı

Fungal izolatın saflaştırılması ve çoğaltılması amacıyla Patates Dekstroz Agar (PDA) besiyeri ve distile su kullanılmıştır. Hazırlanan besiyeri, 121.1°C'de 15 dakika boyunca otoklavda sterilize edildikten sonra steril petri kaplarına aktarılmıştır. Hazırlanan besiyerleri hem ön kültür elde edilmesi hem de uygulama grupları için zemin oluşturmuştur. Uygulama gruplarına uçucu yağın farklı konsantrasyonları ilave edilmiştir (5 µl, 10 µl, 20 µl) ve steril pipet ucu ile homojen bir şekilde karıştırılmıştır.

Fungal İzolatın Hazırlanması

Fungal izolatlar, hazırlanan 90 mm'lik petri kaplarındaki besiyeri üzerine yerleştirilerek optimum sıcaklık ve nem koşullarında 7 gün boyunca inkübasyona bırakılmıştır.

Antifungal Aktivite Testi

İnokülasyona hazır *A. alternata* petrilerinden 8 mm çapındaki fungal diskler steril bir fungus delici yardımıyla alınarak PDA ortamının merkezine inoküle edilmiştir. Fungusların gelişimi, petri kaplarını tamamen kaplayacak şekilde inkübasyona bırakılmıştır. Denemeler üç tekerrürlü olarak gerçekleştirilmiştir. Ayrıca, çalışmada pozitif (nistatin) ve negatif kontrol (uçucu yağ içermeyen) grupları kullanılmıştır.
İnkübasyon süresi sonunda fungal koloni çapları ölçülerek elde edilen veriler doğrultusunda solüsyonların antifungal etkinliği hesaplanmıştır (Benjilali ve ark. 1984). Hesaplama aşamasında, başlangıçta yerleştirilen 8 mm çapındaki fungal diskler değerlendirmeye dahil edilmemiştir. Solüsyonların antifungal etkisi, Deans ve Svoboda (1990) tarafından belirtilen % inhibisyon formülü kullanılarak belirlenmiştir:
İnhibisyon (%) = (gc - gt) / gc × 100(gc: kontrol gruplarındaki miselyal büyüme çapı, gt: uçucu yağ uygulanmış ortamdaki miselyal büyüme çapı).

İstatistiki Analiz

Farklı yıllar ve dozlardan elde edilen veriler tesadüf parselleri deneme deseninde 3 tekrarlı olarak faktöriyel düzenlemeye göre SAS (2009) istatistik paket programında GLM prosedürü kullanılarak standart varyans analizi tekniğinde (ANOVA) analiz edilmiş ve ortalamalar arasındaki farklılıklar LSD çoklu karşılaştırma testine göre belirlenmiştir.

Bulgular ve Tartışma

Esansiyel yağların fitopatojen funguslara karşı etkinliği, son yıllarda bitki hastalıklarının kontrolünde doğal ve çevre dostu alternatifler arayışı nedeniyle yoğun bir şekilde araştırılmaktadır (Šernaitė ve ark., 2020). Bu yağlar,

kompleks kimyasal yapıları ve çeşitli biyoaktif bileşenleri sayesinde geniş spektrumlu antifungal aktivite göstermektedir. Örneğin, dereotu (*Anethum graveolens* L.) tohum yağı, *Aspergillus flavus* üzerinde antifungal etki göstermiştir. Uçucu yağ, ergosterol sentezini inhibe ederek plazma membranında hasara neden olmuş ve hücre morfolojisini değiştirmiştir. Ayrıca, mitokondriyal membran potansiyelini (MMP) artırmış, ATPaz ve dehidrojenaz aktivitelerini azaltmış ve glikoz kaynaklı pH düşüşünü engellemiştir. Bu mitokondriyal disfonksiyon, reaktif oksijen türleri (ROS) birikimine yol açarak hücre canlılığını azaltmıştır. L-sistein eklenmesiyle ROS etkisinin önlenmesi, ROS'un antifungal mekanizmadaki önemli rolünü doğrulamaktadır (Tian ve ark., 2011).. Esansiyel yağların antifungal etki mekanizmaları arasında hücre zarı bütünlüğünün bozulması, hücre içi pH'nın değişmesi ve ATP üretiminin engellenmesi yer almaktadır (Prakash ve ark., 2012). Bununla birlikte, esansiyel yağların etkinliği hedef patojene göre değişiklik gösterebilmektedir (Kishore ve ark., 2007). Sonuç olarak, esansiyel yağlar, sentetik fungisitlere alternatif olarak sürdürülebilir tarım uygulamalarında kullanılabilecek doğal antifungal ajanlar olarak öne çıkmaktadır.

Uçucu yağlar farklı fitopatojen mikroorganizmalar üzerine gelişimi engelleyici etkiye sahiptir. Çok sayıda çalışma bitki hastalıklarının kontrolünde kimyasal ilaçlara göre çevre dostu organik kaynaklar olmalarından dolayı uçucu yağların kullanımına odaklanmıştır. Öğrek otu da güçlü antifungal etkiye sahip bitkisel kaynaklardan biridir. Başka bir çalışmada, Türkiye'de yetişen *H. platytaenium* Boiss. türünün havai kısımlarından (gövde, yaprak, çiçek ve meyve gibi toprak üstünde bulunan bölümleri) elde edilen uçucu yağın bileşimi GC-MS yöntemiyle belirlenmiştir. Uçucu yağın %95,24'ünü oluşturan 22 bileşen tespit edilmiştir. Yağın ana bileşenleri oktil asetat (%85,53), oktil hekzanoat (%3,06), (Z)-4-oktenil asetat (%1,60) ve oktil oktanoat (%1,24) olarak bulunmuştur. Bu çalışmada, ayrıca, *H. platytaenium* uçucu yağının çeşitli maya ve bakteri türlerine karşı antimikrobiyal aktivitesi disk difüzyon yöntemi kullanılarak araştırılmıştır. Ekstrakt, *Candida glabrata* üzerinde 12-32 mm arasında değişen inhibisyon zonları ile güçlü bir antimikrobiyal aktivite göstermiştir. Buna karşın, test edilen tüm bakterilerin büyümesi ekstrakttan etkilenmemiştir. Sonuç olarak, bu çalışma *H. platytaenium* uçucu yağının doğal bir antikandidal kaynak olarak değerlendirilebileceğini göstermektedir (Akcin ve ark., 2013).

Başka bir çalışmada *H. platytaenium* uçucu yağının çeşitli bitki patojenleri üzerindeki antifungal etkileri araştırılmıştır. Yapılan bileşen analizi sonucunda, uçucu yağın 12 farklı bileşen içerdiği belirlenmiş olup, ana bileşenler myristicin (%27.47) ve octyl acetate (%25.10) olarak tespit edilmiştir. Deneyler sonucunda, 10 µl uçucu yağın *Fusarium oxysporum*, *Rhizoctonia solani* ve *Sclerotinia sclerotiorum* türlerinin büyümesini tamamen inhibe ettiği görülmüştür. Çeşitli patojenler için etkili konsantrasyon (LC90) değerleri belirlenmiştir. Çalışmada, bu yağın bitki hastalıklarıyla mücadelede doğal bir alternatif olarak kullanılma potansiyeline sahip olduğu gösterilmiştir (Bayan ve ark., 2016).
Bu çalışmada, öğrek otu uçucu yağının *Alternaria alternata*'ya karşı antifungal etkisi, ekstraksiyon yılına bağlı olarak değerlendirilmiştir. Tablo 1'de sunulan verilere göre, uçucu yağın farklı konsantrasyonları fungusun miseliyal gelişimini baskılamış ve artan dozlarla birlikte inhibisyon oranlarında belirgin bir artış gözlenmiştir.
Özellikle 20 µL dozu, her iki ekstraksiyon yılında da en yüksek inhibisyon oranlarını sağlamış olup, 2022 yılına ait uçucu yağ %76,6 - %75,5 oranlarında inhibisyon gösterirken, 2021 yılına ait yağ %77,7 - %86,6 arasında değişen oranlarda antifungal etki sergilemiştir. Bu durum, uçucu yağın biyolojik aktivitesinin ekstraksiyon yılına bağlı olarak değişebileceğini ve farklı yıllarda elde edilen örneklerde bileşen miktarlarının farklılık gösterebileceğini düşündürmektedir. Literatürde bu uçucu yağ üzerine yapılmış neredeyse hiçbir çalışma bulunmadığından, bu çalışmamızın özgün ve güncel olduğunu göstermektedir.
Daha düşük konsantrasyonlarda (5 µL ve 10 µL) ise inhibisyon etkisinin belirgin olduğu ancak maksimum düzeye ulaşmadığı görülmüştür. 5 µL dozunda %27,7 - %35,5, 10 µL dozunda ise %31,1 - %62,2 arasında değişen inhibisyon değerleri kaydedilmiştir. Bu bulgular, doz bağımlı bir antifungal etkinin varlığını ortaya koymakta ve özellikle yüksek konsantrasyonlarda uçucu yağın güçlü bir biyofungisit olabileceğini desteklemektedir. Çalışma kapsamında elde edilen veriler Tablo 1 ve Tablo 2'de sunulmuştur.
Türün farklı yıllarda ve dozlarda uygulanan uçucu yağı ile dozxyıl interaksiyonu *A. alternata*'ya karşı antifungal etkisi istatiksel olarak ($p<0.01$) önemli bulunmuştur (Tablo 1).

Tablo 1. Ekstraksiyon yılına bağlı olarak elde edilen *H. platytaenium* uçucu yağının antifungal aktivitesine ait varyans analiz sonuçları

Varyasyon kaynakları	Serbestlik derecesi	Kareler toplamı	Kareler ortalaması	F değeri
Yıl	1	202.8	202.8	30.88**
Doz	4	25647.2	6411.8	976.42**
Yıl x Doz	4	460.53	115.13	17.53**
Hata	20	131.3	6.67	
Genel	29			
Cv	5.1			

H. platytaenium türünün 2021 yılı meyvelerinden elde edilen uçucu yağı 47.5 mm inhibisyon çapına sahip olurken 2022 yılında elde edilen yağı 52.7 mm çapa sahip olmuştur. Farklı dozlarda uygulanan *H. platytaenium* uçucu yağında en düşük antifungal etki 5 µL uygulamasında 69.7 mm olurken doz artışına bağlı olarak antifungal etki artarak 20 µL uygulamasında 29.3 mm olarak belirlenmiştir.

Tablo 2. Ekstraksiyon yılına bağlı olarak elde edilen *H. platytaenium* uçucu yağının antifungal aktivitesini gösteren miseliyal ölçümler

	Negatif Kontrol	**Pozitif Kontrol**	**5 µL**	**10 µL**	**20 µL**	**Ortalama**
2021	90 a	8.0 f	68.7 b	44.7 d	26.0 e	47.5 B
2022	90 a	8.0 f	70.1 bc	65.3 c	29.3 e	52.7 A
Ortalama	90 A	8 E	69.7 C	55.0 C	27.7 D	
$Lsd_{yıl}$:1.95	Lsd_{doz}: 3.09	$Lsd_{yılxdoz}$: 4.58				

Ek olarak, farklı ekstraksiyon yıllarına ait uçucu yağlar karşılaştırıldığında, 2021 yılına ait örneklerin inhibisyon etkisinin genel olarak daha yüksek olduğu gözlenmiştir. Bu farklılık, uçucu yağın kimyasal bileşiminin çevresel faktörlerden, hasat zamanından veya depolama koşullarından etkilenebileceğini göstermektedir. Uçucu yağın ana bileşenleri arasında bulunan n-oktil asetat, apiyol ve elemisin gibi fitokimyasal bileşiklerin antifungal etkiye katkıda bulunabileceği düşünülmektedir (Kılıç ve ark., 2016; Karan ve Genc, 2018).

Sonuç olarak, *H. platytaenium* uçucu yağı, *A. alternata*'nın misel gelişimini baskılayarak bitki hastalıklarıyla biyolojik mücadelede alternatif bir antifungal ajan olarak değerlendirilebilir. Ancak, bileşen profili ve etkinliği üzerinde ekstraksiyon yılı, çevresel faktörler ve doz gibi değişkenlerin etkili olduğu görülmektedir. Gelecekteki çalışmalar, bu faktörlerin uçucu yağın antifungal aktivitesi üzerindeki etkilerini daha detaylı incelemeli ve farklı patojen türleri ile genişletilmelidir.

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Can *H. platytaenium* Essential Oil Be Used as a Biopesticide Against White Mold Disease?

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Abstract

This study evaluates the in vitro antifungal potential of Heracleum platytaenium essential oil against Sclerotinia sclerotiorum, a widespread phytopathogenic fungus that causes significant economic losses in agricultural production. Although chemical fungicides are commonly used for its control, concerns regarding environmental impact and human health have increased interest in plant-based antifungal agents as sustainable alternatives.
In this study, commercially obtained *H. platytaenium* essential oil was tested at three different concentrations (5 µL, 10 µL, and 20 µL) to assess its inhibitory effects on fungal mycelial growth. The experiments were conducted with negative control (fungus growing without treatment) and positive control (nistatin application). The results demonstrated that higher concentrations of the essential oil significantly suppressed fungal growth. Particularly, at 20 µL concentration, both extraction years exhibited strong antifungal activity, with inhibition rates ranging from 97.7% to 100%. Additionally, at lower doses (5 µL), the 2021 extract showed higher antifungal efficacy compared to the 2022 extract.
These findings highlight the potential of H. platytaenium essential oil as a natural antifungal agent for plant disease management. The differences in antifungal activity observed between extraction years suggest that factors such as plant growth conditions, harvest time, and extraction methods may influence the oil's efficacy. Further studies are needed to explore its chemical composition, antifungal mechanisms, and potential applications in agricultural practices.

Key Words: *Heracleum platytaenium, Essential oil, Antifungal activity, Sclerotinia sclerotiorum*

Heracleum Platytaenium Boiss. (Endemik) Uçucu Yağı Beyaz Çürüklük Hastalığına Karşı Biyopestisit Olarak Kullanılabilir mi?

Özet

Çalışmada, *Heracleum platytaenium* uçucu yağının *Sclerotinia sclerotiorum* fitopatojeni üzerine in vitro antifungal etkilerinin belirlenmesi amacı ile yürütülmüştür. S. *sclerotiorum,* tarımsal üretimde ciddi ekonomik kayıplara yol açan yaygın bir fitopatojen fungus olup, genellikle kimyasal fungisitlerle kontrol altına alınmaktadır. Ancak, çevresel etkiler ve insan sağlığı üzerindeki olumsuz etkiler nedeniyle bitkisel bazlı antifungal ajanlar sürdürülebilir alternatifler olarak öne çıkmaktadır.
Çalışma, negatif kontrol (fungus gelişimi için herhangi bir uygulama yapılmayan ortam) ve pozitif kontrol (nistatin uygulaması) ve *H. platytaenium* uçucu yağı 5 µL, 10 µL ve 20 µL olmak üzere üç farklı konsantrasyonda test edilerek, fungusun miseliyal büyümesi üzerindeki etkileri incelenmiştir. Sonuçlar, yağın daha yüksek konsantrasyonlarının fungus gelişimini önemli ölçüde baskıladığını ortaya koymuştur
H. platytaenium uçucu yağının bitki hastalıklarıyla mücadelede doğal bir antifungal ajan olarak kullanılma potansiyeline sahip olduğunu göstermektedir. Gelecekte yapılacak çalışmalar, yağın kimyasal bileşimi, antifungal mekanizmaları ve tarımsal uygulamalardaki potansiyel kullanımını daha ayrıntılı şekilde ortaya koyacaktır.

Anahtar Kelimeler: *Heracleum platytaenium, Esansiyel yağ, Antifungal aktivite, Sclerotinia sclerotiorum*

Giriş

Sclerotinia sclerotiorum, dünya genelinde yaygın olarak görülen ve tarımsal üretime ciddi zararlar veren önemli bir fitopatojenik fungustur. Ilıman ve nemli iklim bölgelerinde sıklıkla rastlanan bu fungus, hava, su, tarım aletleri, hayvanlar ve enfekte tohumlar aracılığıyla yayılabilir (Purdy, 1979; Bolton ve ark., 2006). Enfeksiyon oluşturma

yeteneği oldukça yüksek olan ve özellikle toprakta uzun süre canlı kalabilen sklerotları sayesinde yıllarca enfeksiyon kaynağı olabilmektedir (Bolton ve ark., 2006). Bu durum, hastalığın kontrol altına alınmasını zorlaştıran en önemli faktörlerden biridir.

Bu patojen, geniş bir konukçu dizisine sahip olup yaklaşık 400'den fazla bitki türünü enfekte edebilmektedir (Purdy, 1979). Tarımsal açıdan önemli bitkiler arasında soya fasulyesi (*Glycine max*), bezelye (*Pisum sativum*), domates (*Solanum lycopersicum*), biber (*Capsicum annuum*), havuç (*Daucus carota*), marul (*Lactuca sativa*), kanola (*Brassica napus*), ayçiçeği (*Helianthus annuus*) ve pamuk (*Gossypium hirsutum*) gibi bitkiler yer almaktadır (Boland ve Hall, 1994; Kim ve ark., 2006; Westrick ve ark., 2019). Bu kadar geniş bir konukçu yelpazesine sahip olması, fungusun ekili alanlarda hızla yayılmasına ve verim kayıplarına neden olmasına yol açmaktadır. Özellikle serin ve nemli hava koşullarında hastalığın şiddeti artmakta, bazı durumlarda %80'e varan ürün kayıplarına sebep olabilmektedir (Amselem ve ark., 2011). Hastalık, sadece verim düşüşüne değil, aynı zamanda meyve ve tohumların çürümesi nedeniyle kalite kaybına ve pazarlanabilirliğin azalmasına da neden olmaktadır (Xu ve ark., 2018). Bunun yanı sıra, depolama sırasında da çürümeye yol açarak ekonomik kayıpları daha da artırmaktadır.

S. sclerotiorum, yaşam döngüsünde sklerot, miselyum ve askospor oluşumuna dayalı bir süreç izler. Fungus, enfekte olmuş bitki dokularında sklerot adı verilen sert ve koyu renkli yapılar oluşturur. Bu sklerotlar, uzun süre toprakta dayanıklı kalarak uygun koşullar oluştuğunda çimlenir ve yeni enfeksiyonlara yol açar (Willetts & Wong, 1980). Çimlenme sonucunda apothecium adı verilen küçük fungal yapılar gelişir ve bu yapılar, askosporları üreterek hastalığın yayılmasını sağlar. Askosporlar hava yoluyla taşınarak bitkilerin yaprak, gövde ve çiçek yüzeylerine tutunur ve burada miselyum gelişimini başlatır (Kohn, 1979; Willbur ve ark., 2019). Fungus, bitki dokularına enzimler salgılayarak hücreleri parçalar ve hızla yayılır. İleri aşamalarda yeni sklerotlar oluşur ve hastalık döngüsü tekrar başlar (Peltier ve ark., 2012).

Enfeksiyonun bitkilerde oluşturduğu belirtiler oldukça belirgindir. Enfekte bitkilerde solgunluk, gövde çürüklüğü, yapraklarda nekroz, su kaybı ve yumuşak çürüklük gibi semptomlar görülür. Özellikle hastalığın ilerleyen evrelerinde, bitkinin enfekte olmuş dokularında pamuk benzeri beyaz miselyal tabaka ve siyah sklerotlar oluşur (Ekins ve ark., 2007; Silva ve ark., 2014; Lehner ve ark., 2016). Meyve ve çiçek enfeksiyonları da oldukça yaygındır ve bu durum, özellikle baklagiller ve yağ bitkileri gibi ürünlerde ciddi ekonomik kayıplara neden olabilir (Rodríguez ve ark., 2004; Zhao ve ark., 2004; Sabaté ve ark., 2018; Hossain ve ark., 2023).

S. sclerotiorum, kimyasal fungisitlerle kontrol altına alınabilse de, fungisit direncinin gelişmesi, çevresel kaygılar ve insan sağlığına yönelik riskler nedeniyle alternatif mücadele yöntemlerine ihtiyaç duyulmaktadır (Gossen ve ark., 2001). Bu nedenle, biyolojik kontrol stratejileri ve bitkisel bazlı antifungal ajanlar üzerine yapılan araştırmalar giderek önem kazanmaktadır. Son yıllarda, uçucu yağların antifungal özellikleri üzerine yapılan çalışmalar artmış ve bazı bitkilerin bu fungusa karşı doğal bileşikler üreterek etkili bir mücadele yöntemi sunabileceği gösterilmiştir (Soylu ve ark., 2007; Bakkali ve ark., 2008; Jiang ve ark., 2013; Türkmen ve Kaya, 2021). *H. platytaenium* gibi uçucu yağ içeriği zengin bitkilerin antimikrobiyal potansiyeli, özellikle çevre dostu ve sürdürülebilir mücadele stratejileri geliştirilmesi açısından büyük bir fırsat sunmaktadır (Iscan ve ark., 2004; Bahadori ve ark., 2016; Karan ve Genc, 2018).

Bu çalışmada, *H. platytaenium* uçucu yağının *S. sclerotiorum* üzerindeki antifungal etkisi araştırılarak, bitkisel bazlı doğal bileşiklerin patojenlerle mücadelede kullanılma potansiyeli değerlendirilecektir. Yapılacak analizlerle, farklı yıllarda ekstrakte edilen bu uçucu yağın fungusa karşı etkinliği belirlenecek ve alternatif biyolojik mücadele yöntemleri geliştirilmesine katkı sağlanacaktır.

Materyal ve Yöntem

Uçucu Yağ ve Test Fungusu

Çalışmada kullanılan *H. platytaenium* bitkisinin uçucu yağı Isparta Uygulamalı Bilimler Üniversitesi, Ziraat Fakültesi Deneme alanlarında yetiştirilmiştir. Türün 100 gr meyveleri öğütüldükten sonra 3 saat boyunca hidrodistilasyona tabi tutulmuştur. Araştırmada test edilen *Sclerotinia sclerotiorum*, Bingöl Üniversitesi Ziraat Fakültesi Fitopatoloji Laboratuvarı'nda bulunan fungus koleksiyonundan elde edilmiştir.

Besiyeri Hazırlığı

Fungal izolatın saflaştırılması ve çoğaltılması amacıyla Patates Dekstroz Agar (PDA) besiyeri hazırlanmış ve distile su ile desteklenmiştir. Besiyeri, 121.1°C'de 15 dakika boyunca otoklavda sterilize edildikten sonra aseptik koşullarda steril petri kaplarına dökülmüştür. Hazırlanan besiyeri, hem ön kültür elde edilmesi hem de uygulama gruplarının oluşturulması için kullanılmıştır. Uygulama gruplarında, uçucu yağın farklı konsantrasyonları (5 µl, 10 µl, 20 µl) besiyerine eklenmiştir.

Fungal İzolatın Hazırlanması

Fungal izolatlar, 90 mm çapındaki petri kaplarına aktarılan besiyeri üzerine yerleştirilmiş ve optimum sıcaklık ve nem koşullarında 7 gün boyunca inkübe edilmiştir.

Antifungal Aktivite Testi

İnokülasyona hazır hale getirilen *S. sclerotiorum* kültürlerinden 8 mm çapındaki miselyal diskler steril bir fungus delici yardımıyla kesilerek PDA ortamının merkezine inoküle edilmiştir. Fungusun gelişimi tamamlanana kadar petri kapları uygun inkübasyon koşullarında muhafaza edilmiştir. Denemeler üç tekerrürlü olarak yürütülmüştür.

Çalışmada, antifungal etkiyi değerlendirmek için pozitif kontrol (nistatin) ve negatif kontrol (uçucu yağ içermeyen ortam) grupları kullanılmıştır.

İnkübasyon süresi sonunda fungal koloni çapları ölçülmüş ve elde edilen veriler doğrultusunda antifungal etkinlik belirlenmiştir (Benjilali ve ark., 1984). Antifungal etki, Deans ve Svoboda (1990) tarafından önerilen şu formüle göre hesaplanmıştır:

İnhibisyon (%) = [(gc - gt) / gc] × 100

(gc: kontrol gruplarındaki miselyal büyüme çapı, gt: uçucu yağ uygulanmış ortamdaki miselyal büyüme çapı).

İstatistiki Analiz

Farklı yıllar ve dozlardan elde edilen veriler tesadüf parselleri deneme deseninde 3 tekrarlı olarak faktöriyel düzenlemeye göre SAS (2009) istatistik paket programında GLM prosedürü kullanılarak standart varyans analizi tekniğinde (ANOVA) analiz edilmiş ve ortalamalar arasındaki farklılıklar LSD çoklu karşılaştırma testine göre belirlenmiştir.

Bulgular ve Tartışma

Esansiyel yağlar, tarımda doğal antifungal ajanlar olarak yaygın bir şekilde kullanılmaktadır. Sentetik fungisitlerin uzun vadeli kullanımı, hem çevresel hem de insan sağlığına zararları nedeniyle alternatif biyolojik kontrol yöntemlerine olan ihtiyacı artırmıştır. Çeşitli bitkisel bazlı esansiyel yağların antifungal özellikleri, in vitro ve in vivo çalışmalarda kanıtlanmıştır (Bakkali ve ark., 2008; Soylu ve ark., 2007).

S. sclerotiorum'un kontrolüne yönelik in vitro çalışmalarda, esansiyel yağların antifungal etkinliğini değerlendirmek için çoğunlukla miselyal büyümeyi inhibe etme yöntemi kullanılmaktadır. Örneğin, *Origanum syriacum* ve *Foeniculum vulgare* esansiyel yağlarının *S. sclerotiorum* miselyal gelişimi üzerine baskılayıcı etkisi belirlenmiştir (Soylu ve ark., 2007). Bir çalışmada, *Ziziphora clinopodioides* Lam. esansiyel yağının (ZCEO) *S. sclerotiorum*'a karşı in vitro ve in vivo etkilerini araştırmıştır. GC-MS analizi, yağın %98,3'ünü oluşturan 21 bileşiği tespit etmiştir; en yüksek bileşikler pulegon (%53,5), izomenton (%10,4) ve karvondur (%5,7). ZCEO, *S. sclerotiorum*'un misel büyümesini, 1,25 µl ml−1 (temas fazı) ve 0,15 µl ml−1 (buhar fazı) konsantrasyonlarında tamamen inhibe etmiştir. Sklerotların çimlenmesi de bu konsantrasyonlarla engellenmiştir. ZCEO, rapsi bitkilerinde (*Brassica napus*) de *S. sclerotiorum*'un büyümesini doz bağımlı olarak inhibe etmiş, fungusun morfolojisinde değişiklikler gözlemlenmiştir. Sonuçlar, ZCEO'nun etkili bir koruma aracı olabileceğini göstermektedir (Ma ve ark., 2016). Başka bir çalışmada, *Piper aduncum* bitkisinin yaprak ve çiçekli dallarından elde edilen esansiyel yağların, *S. sclerotiorum* fungusunun misel büyümesi üzerindeki etkisi incelenmiştir. Esansiyel yağlar, hidrodistilasyon ile elde edilip GC-MS ve GC-FID ile analiz edilmiştir. *P. aduncum* yağlarında bulunan başlıca bileşikler arasında piperiton (%23,4), miristikin (%12,4), terpin-4-ol (%12,3), β-karyofilen (%7,2), α-humulen (%6,9), germakren-D (%6,9) ve dillapiol (%6,3) yer aldığı tespit edilmiştir. In vitro testler, bu esansiyel yağının 30 µL dozda etmenin misel büyümesini %100'e yakın oranda inhibe ettiğini göstermiştir. Sonuçlar, bu esansiyel yağların *S. sclerotiorum* üzerinde yüksek potansiyele sahip olduğunu ortaya koymuştur (Valadares ve ark., 2018). Elgorbany ve ark. (2015), soğan (*Allium cepa*), çörek otu (*Nigella sativa*) ve okaliptüs (*Eucalyptus globulus*) esansiyel yağlarının beş farklı fitopatojen fungusa (*Fusarium oxysporum f.sp. melonis*, *F. solani*, *F. verticillioides*, *S. sclerotiorum* ve *R. solani*) karşı antifungal etkilerini değerlendirilmiştir. Soğan ve okaliptüs esansiyel yağları, 500 ppm konsantrasyonda bazı fungus türlerinin miseliyal büyümesini tamamen inhibe etmiştir. Çörek otu yağı ise farklı patojenlere karşı değişen oranlarda antifungal aktivite göstermiştir. Soğan esansiyel yağı, *F. oxysporum f.sp. melonis* ve *F. solani*'nin spor çimlenmesini tamamen engellerken, okaliptüs yağı *F. oxysporum f. sp. melonis* ve *F. verticillioides* üzerinde yüksek oranda inhibisyon sağlamıştır. Sonuçlar, özellikle soğan ve okaliptüs esansiyel yağlarının biyofungisit olarak kullanılabileceğini göstermiştir.

Heracleum cinsine ait farklı bitkilerden elde edilen uçucu yağlar ve ekstraktlar üzerine çeşitli çalışmalar yapılmış olsa da, bu çalışmada kullanılan *H. platytaenium* bitkisinin antifungal aktivitesine ilişkin araştırmalar oldukça sınırlıdır. Ancak, Heracleum türlerinin esansiyel yağlarının antimikrobiyal ve antifungal özelliklerini inceleyen önceki çalışmalar, bu yağların çeşitli patojen mikroorganizmalara karşı etkili olduğunu ortaya koymuştur (Torbati ve ark., 2013). Esansiyel yağların bitki patojenleri üzerinde doğrudan temas veya volatil bileşenler aracılığıyla baskılayıcı etki gösterebildiği de bilinmektedir (Jiang ve ark., 2013). Örneğin, *H. platytaenium* esansiyel yağının gıda kontaminantı olan *Penicillium verrucosum*'un büyümesini engellediği gösterilmiştir (Özçakmak, 2012).

Bu çalışmada, farklı yıllarda elde edilen öğrek otu (*H. platytaenium*) esansiyel yağının, *S. sclerotiorum* etmenine karşı antifungal aktivitesi üç farklı doz kullanılarak değerlendirilmiştir. Üç tekerrürlü olarak gerçekleştirilen testler, artan konsantrasyonların miseliyal gelişimi baskıladığını doğrulamıştır. Bu bulgular, mevcut çalışmanın kendi alanında yürütülen diğer benzer çalışmaların sonuçlarıyla parallelik göstermektedir. Türkiye'de gerçekleştirilen bir araştırmada, *H. platytaenium* esansiyel yağının *Fusarium oxysporum*, *Rhizoctonia solani* ve *Sclerotinia sclerotiorum* gibi fitopatojenlere karşı güçlü antifungal aktivite sergilediği tespit edilmiştir (Bayan ve ark., 2016). Bu çalışmada, ekstraksiyon yılına bağlı olarak gerçekleştirilen miseliyal ölçümler ve yüzde inhibisyon değerleri aşağıdaki tablolarda detaylandırılmıştır.

Farklı yıllarda hasat edilen, farklı dozlarda uygulanan ve yıllara bağlı olarak *H. platytaenium* uçucu yağının dozlarının göstermiş olduğu antifungal istatiksel olarak ($p<0.01$) önemli bulunmuştur.

Tablo 1. Ekstraksiyon yılına bağlı olarak elde edilen *H. platytaenium* uçucu yağının antifungal aktivitesine ait varyans analiz sonuçları

Varyasyon kaynakları	Serbestlik derecesi	Kareler toplamı	Kareler ortalaması	F değeri
Yıl	1	45.6333	45.63	33.39**
Doz	4	36617.2	6698.24	6698.27**
Yıl x Doz	4	127.2	23.27	23.27**
Hata	20	27.333		
Genel	29			
Cv	2.61			

Yıllara bağlı olarak en düşük inhibisyona çapı 2022 yılında 43.53 mm olurken 2021 yılında 46.0 mm olarak ölçülmüştür. Dozlara bağlı olarak en düşük inhibisyon çapı istatiksel olarak aynı grup içerisinde yer 20 µL (8.7 mm) ve pozitif kontrol grubunda (8.0 mm) belirlenirken en yüksek inhibiyon çapı negatif kontrol grubunda (90.0) olarak belirlenmiştir. 2021 ve 2022 yıllarında bağlı olarak uygulama dozları en düşük inhibisyon çapı istatiksel olarak aynı grup içerisinde yere alan pozitif kontrol ve 20 µL uygularında tespit edilirken uygulamalara arasında en yüksek inhibisyon çapı 5 µL dozunda tespit edilmiştir.

Tablo 2. Ekstraksiyon yılına bağlı olarak elde edilen *H. platytaenium* uçucu yağının antifungal aktivitesini gösteren miseliyal ölçümleri mm

	Negatif Kontrol	Pozitif Kontrol	5 µL	10 µL	20 µL	Ortalama
2021	90 a	8.0 e	81.7 b	41.3 c	9.0 e	46.0 A
2022	90 a	8.0 e	80.7 b	30.7 d	8.3 e	43.53 B
Ortalama	90 A	8.0 D	81.2 B	36.0 C	8.7 D	
$Lsd_{yıl}$:0.89	Lsd_{doz}: 1.41	$Lsd_{yılxdoz}$: 2.01				

Tablo 2'e göre, negatif kontrol grubunda fungus gelişimi devam etmiş ve büyüme oranı %90 olarak belirlenmiştir. Pozitif kontrol grubunda ise standart antifungal ajan kullanılmış ve fungusun gelişimi tamamen inhibe edilerek %100 inhibisyon sağlanmıştır. Deney gruplarında farklı dozlarda (5 µL, 10 µL, 20 µL) uçucu yağ uygulanarak inhibisyon oranları karşılaştırılmıştır. 5 µL dozunda, 2022 yılı ekstraktının inhibisyon oranı %17,7 ile %20 arasında değişirken, 2021 yılı ekstraktı %14,4 ile %42,2 arasında değişen bir inhibisyon göstermiştir. Bu dozda, 2021 yılı ekstraktı bazı tekrarlar için daha yüksek antifungal aktivite göstermiştir. 10 µL dozunda, 2022 yılı ekstraktı %73,3 ile %75,5 arasında değişen bir inhibisyon sağlarken, 2021 yılı ekstraktı %62,2 ile %64,4 arasında inhibisyon göstermiştir. Bu seviyede, 2022 yılı ekstraktı daha güçlü bir antifungal etki sergilemiştir. 20 µL dozunda, 2022 yılı ekstraktı %98,8 ile %100 arasında değişen bir inhibisyon oranına ulaşırken, 2021 yılı ekstraktı %97,7 ile %100 arasında inhibisyon sağlamıştır. Yüksek dozda her iki yılın ekstraktı da neredeyse eşit düzeyde ve oldukça güçlü bir antifungal etki göstermiştir.

Sonuçlar, *H. platytaenium* uçucu yağının doz bağımlı bir antifungal etkiye sahip olduğunu ve özellikle yüksek dozlarda fungus gelişimini büyük ölçüde baskıladığını göstermektedir. Farklı yıllarda elde edilen ekstraktlar arasında belirli oranlarda farklılıklar gözlemlense de, genel olarak güçlü antifungal aktivite sergiledikleri belirlenmiştir. Bu çalışmanın bulguları, daha önce yapılan benzer çalışmalarla karşılaştırıldığında önemli benzerlikler ve farklılıklar gözlemlenmiştir. Soylu ve ark. (2007) kekik ve rezene esansiyel yağlarının *S. sclerotiorum* miselyal gelişimini %80'den fazla inhibe ettiğini bildirmiştir. Benzer şekilde, Jiang ve ark. (2013) tarçın yağının bu fungusa karşı yüksek antifungal etki gösterdiğini ortaya koymuştur. Bizim çalışmamızda da benzer inhibisyon düzeyleri kaydedilmiş olup, 20 µL dozundaki tam inhibisyon sonucu diğer çalışmalarla uyumluluk göstermektedir.

H. platytaenium esansiyel yağına dair önceki araştırmalarda, miristisin (%27.47), oktil asetat (%25.10) ve 1-oktanol (%16.90) bileşenlerinin öne çıktığı ve antifungal etkinliği desteklediği bildirilmiştir (Bayan ve ark., 2016). Kılıç ve Dirmenci (2016)'in analizleri öğrek otu esansiyel yağının %95,24'ünü oluşturan 22 bileşen tespit etmiştir. Başlıca bileşenler, oktil asetat (%85,53), oktil hekzanoat (%3,06), (Z)-4-oktenil asetat (%1,60) ve oktil oktanoat (%1,24) olarak belirlenmiştir. Esansiyel yağların antimikrobiyal etkisi, bileşenlerinin kalite ve miktarına bağlıdır. Bu bileşenler ise bitkinin yetiştiği çevresel koşullar ve ekstraksiyon yöntemleri gibi faktörlerden etkilenmektedir (Reyes-Jurado ve ark., 2015; Kakaraparthi ve ark., 2014; Bahadori ve ark., 2016; Mechergui ve ark., 2016). Çalışmada, farklı yıllarda ekstrakte edilen yağlar arasındaki aktivite farklılığı dikkat çekicidir. Özellikle 5 µL dozundaki antifungal etki, 2021 ekstraktında 2022'ye göre belirgin olarak yüksekken, diğer testlerde 2022 yılında ekstrakte edilen esansiyel daha fazla antifungal aktivite sergilemiştir. 2021 yılında ekstrakte edilen yağın 5 µL dozunda daha etkili olması, belirli bir aktif bileşenin (örneğin, fenolik bileşikler veya monoterpenler gibi) düşük

dozlarda daha konsantre halde bulunmasından kaynaklanabilir. Ancak, daha yüksek dozlarda bu bileşenlerin etkileşimi veya diğer bileşiklerin baskın hale gelmesi, 2022 ekstraktını daha güçlü kılabilir.
Sonuç olarak, *H. platytaenium* esansiyel yağının *S. sclerotiorum* üzerindeki antifungal etkinliği kanıtlanmış olup, doğru doz ve ekstraksiyon koşulları optimize edilerek biyolojik mücadelede kullanılma potansiyeli araştırılmalıdır.

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In Vitro Tyrosinase and Collagenase Inhibitory Potential of *Consolida orientalis* from Türkiye

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Abstract

The cosmetics sector is showing significant growth especially on skin aging. For this reason, it is known that studies on natural products that prevent aging and pigmentation are popular research areas. Antioxidants protect our skin from free radicals and help us prevent signs of aging and skin tone inequalities. High tyrosinase inhibition has a whitening effect on the skin, while collagenase inhibition has an anti-sagging effect on the skin. Antioxidant activity and tyrosinase/collagenase enzyme inhibition capacities support each other. This study aimed to determine the tyrosinase and collagenase enzyme inhibition potentials of ethanol extracts of *Consolida orientalis* flowers, whose antioxidant activity has been proven in the literature. In the study; kojic acid was used as the standard substance for anti-tyrosinase activity, and quercetin was used as the standard substance for anti-collagenase activity. According to the enzyme inhibitory capacity results measured with both analyses; anti-tyrosinase activity was determined as 13.0% and anti-collagenase activity as 23.2%. These results have shown us that the flowers of *C. orientalis* have the potential to inhibit tyrosinase and collagenase enzymes, although not at a high level. *C. orientalis* deserves further study and can be considered as a new candidate for the development of plant-based products for the management of hyperpigmentation and skin aging.

Key Words: *Collagenase, Consolida orientalis, Tyrosinase, Natural cosmetics*

Türkiye'den *Consolida orientalis*'in İn Vitro Tirozinaz ve Kollajenaz İnhibitör Potansiyeli

Özet

Kozmetik sektörü özellikle cilt yaşlanması üzerine ciddi bir büyüme göstermekte. Bu nedenle yaşlanma ve pigmentasyonu önleyen doğal kaynaklı ürünler üzerine yapılan çalışmaların popüler araştırma alanlarından olduğu bilinmektedir. Antioksidanlar cildimizi serbest radikallerden koruyarak yaşlılık belirtilerinin, cilt tonu eşitsizliklerinin önüne geçmemizde fayda sağlar. Yüksek tirozinaz inhibisyonu ciltte beyazlatma etkisi, kollajenaz inhibisyonu ise ciltte sarkma karşıtı etki göstermektedir. Antioksidan aktivite ve tirozinaz/kollajenaz enzim inhibisyon kapasiteleri birbirini destekleyen etkiler göstermektedir. Bu çalışma ile; antioksidan etkinliği literatürde kanıtlanmış olan *Consolida orientalis* çiçeklerinin etanol ekstrelerinin tirozinaz ve kollajenaz enzim inhibisyon potansiyellerini belirlemek amaçlanmıştır. Çalışmada; anti-tirozinaz aktivite için standart madde olarak kojik asit, anti-kollajenaz aktivite için standart madde olarak ise kersetin kullanılmıştır. Her iki analizle de ölçülen enzim inhibitör kapasite sonuçlarına göre; anti-tirozinaz aktivite %13.0, anti-kollajenaz aktivite %23.2 şeklinde belirlenmiştir. Bu sonuçlar bize; *C. orientalis* bitkisine ait çiçeklerin tirozinaz ve kollajenaz enzimini inhibe etme potansiyellerinin yüksek seviyede olmasa da varolduğunu göstermiştir. *C. orientalis* daha fazla çalışmayı hak eden, hiperpigmentasyon ve cilt yaşlanması yönetimine yönelik bitki kaynaklı ürün geliştirilmesi için yeni bir aday olarak değerlendirilebilir.

Anahtar kelimeler: *Kollajenaz, Consolida orientalis, Tirozinaz, Doğal kozmetikler*

Giriş

Consolida cinsi, Ranunculaceae familyasına ait, Batı Avrupa, Akdeniz ve Asya gibi dünyanın birçok yerinde doğal olarak yetişen yaklaşık 52 türden oluşan bir cinstir. *Consolida* cinsinin birçok üyesi, fenolikler ve alkaloitler gibi önemli fitokimyasallar içerir (Abbas Ali Dehpour, 2016; Rocchetti et al., 2020). Türkiye florası Ranunculaceae familyasından *Consolida* cinsine ait türler bakımından oldukça zengindir. 14 ü endemik olmak üzere 29 ayrı türün bulunduğu bilinmektedir (Ertuğrul, Arslan, & Tugay, 2010; Liu et al., 2018). *Consolida orientalis* orta-uzun boylu, yapışkan-tüylü tek yıllık bir bitki olup, 20-74 cm uzunluğunda basit veya dallı gövdeleri ve çok sayıda şeritsi-kılıç yaprakları bulunmaktadır. Çiçekler mor renkte ve yoğun salkım şeklindedir. Kurutulmuş ve taze kesme çiçek

bitkileri olarak kesme çiçek ticaretinde ve kuru bitki tasarımlarında sıkça tercih edilir (Mansuroglu, Karaguzel, & Ortacesme, 2009).

Consolida orientalis'in sahip olduğu biyolojik aktiviteden başlıca flavonoidler olmak üzere, fenolik asitler, tirozol türevleri, diterpen alkaloitler, lignanlar ve stilbenler sorumludur (Abbas Ali Dehpour, 2016; Rocchetti et al., 2020). Daha önce yapılan *in vivo* ve *in vitro* çalışmalar; antiparaziter, antifungal, antiviral, antikanser, antioksidan ve böcek öldürücü etkiler de dahil olmak üzere bir dizi biyolojik aktiviteye sahip olduğunu göstermiştir (A.A. Dehpour, Ebrahimzadeh, Roudgar, Nabavi, & Nabavi, 2011; Abbas Ali Dehpour, 2016; Nemati, Dehpouri, Eslami, Mahdavi, & Mirzanejad, 2013).

Hastalıkların meydana gelişi ve yaşlanma sürecini etkileyen en önemli olaylardan birinin oksidatif stres olduğu ile ilgili teoriler oldukça güçlüdür ve üzerinde çalışmalar devam etmektedir. Yaşam süresince oksidan ve antioksidan sistemler arasında denge durumunun bozulması oksidatif strese neden olur. Bu dengenin bozulması sonucunda da oksidatif hasar meydana gelir ve yaşlanmanın ana mekanizması incelendiğinde zamana bağlı oksidatif hasar birincil sebep olarak önemlidir. Organizmanın kendi mekanizmasında ürettiği doğal antioksidanlar yaş ile birlikte azalır. Bu sebeple bitkisel kaynaklı doğal antioksidanların dışardan alımı sistemdeki dengenin düzenlenmesine olanak sağlar (İlgün, Yıldırım, Karagül, & Şeker Karatoprak, 2024).

Bu şekilde enzimler ve enzim inhibitörleri özellikle tıp, gıda ve kozmetik endüstrisi, pestisit üretimi ve tarım endüstrisi olmak üzere birçok alanda kullanılmaktadır (Yan, Y. Jing, Zhixiang, & Suying, 2010). Tirozinaz enzimi, monofenollerin oksidasyonunu katalize eden bakır içeren bir enzimdir ve aynı zamanda melanin biyosentezinde rol oynar. Melanin pigmentini doğada birçok canlıda (hayvanlar, bitkiler, mantarlar, bakteriler) özellikle hayvanlarda bulmak mümkündür (Bilgin Sökmen & Yılmazoğlu, 2018). İnsanlarda melanin, hem serbest radikalleri absorbe etmede hem de organizmayı zararlı UV ışınlarından korumada çok önemli bir rol oynar (Zengin et al., 2019). Kalıtsal ve çevresel faktörlerin cilt rengi sorunlarının başlıca nedenleri arasında olduğu bilinmektedir. Bu dermatolojik olaylar arasında melazma, solar melanosis, ephelides, senil lentigolar ve akne izleri yer almaktadır (Trivedi, Yang, & Cho, 2017). Tirozinaz inhibitörleri cilt bakım sektöründe, özellikle lekeli ciltler için açıcı olarak sıklıkla kullanılmaktadır. Sentetik tirozinaz inhibitörleri içeren cilt ürünleri kızarıklık, kaşıntı ve gelecekte cilt kanseri gibi olumsuz etkilere sahiptir (Pillaiyar, Manickam, & Namasivayam, 2017). Tirozinaz inhibitörleri güçlü antioksidan aktiviteye sahiptir. Çünkü yüksek miktarda güneş ışığı alan bitkiler kendilerini güneşin zararlı ışınlarından korumak için oksijen radikallerini aktive eder. Bu nedenle bitkilerin kendilerini hasardan korumak için güçlü antioksidan etkilere sahip olması gerekir (Masuda, Yamashita, Takeda, & Yonemori, 2005). Sentetik moleküllerle ilgili sağlık endişeleri nedeniyle, hiperpigmentasyonun tedavisi için yeni bileşiklerin geliştirilmesinde doğal ürünlere olan ilgi yeniden canlanmıştır. Benzer biyolojik etkilere, enzim inaktivasyonuna ve antioksidan aktiviteye sahip yeni fitokimyasal bileşiklerin keşfi arzu edilir (Zengin et al., 2019).

Kolajenazlar, organ gelişimi ve doku rejenerasyonunun fizyolojik süreçlerinden sorumlu olan ve cilt yaşlanmasında doğrudan rol oynayan, ekstraselüler matris yeniden şekillenmesi ve bozulmasında yer alan proteolitik enzimlerdir. Kolajenazlar ayrıca hücre büyümesini ve sağ kalımını kontrol edebilen büyüme faktörleri gibi birçok matris ve matris dışı proteinin bozulmasında da yer alır (Freitas-Rodríguez, Folgueras, & López-Otín, 2017; Silva et al., 2024). Cilt yaşlanması, insan vücudunda kaçınılmaz bir biyolojik süreçtir ve yalnızca artan yaştan değil, aynı zamanda hem kronolojik hem de foto-yaşlanmadan da kaynaklanır. Foto-yaşlanma örnekleri arasında ultraviyole ışınlarına, kirliliğe veya nikotine maruz kalma yer alır. Bu yaşlanma sürecinde epidermis incelir ve kan damarları azalır. Bu hasarın elastik liflerin, kolajen liflerinin ve hyaluronik asidin bozulması ve üst dermal bağ dokusunda önemli dejeneratif değişiklikler sonucu meydana geldiği bilinmektedir. Bunun fibroblastlarda ve çeşitli inflamatuar hücrelerde üretilen elastaz, kolajenaz ve hyaluronidazın artan ekspresyonundan kaynaklandığı düşünülmektedir (Farage, Miller, Elsner, & Maibach, 2013; Lee, Cho, Park, & Choi, 2001).

Son yıllarda, bu bitkinin kozmetik ve farmasötik alanlarda potansiyel kullanımını değerlendirmek amacıyla yapılan in vitro çalışmalar artmıştır. Özellikle tirozinaz ve kollajenaz enzim inhibitör aktiviteleri, cilt hiperpigmentasyonu ve yaşlanma karşıtı tedavilerde önemli hedeflerdir. Çalışmamızın amacı, Türkiye'de yetişen *Consolida orientalis* bitkisine ait çiçeklerle hazırlanmış etanol ekstraktlarının tirozinaz ve kollajenaz enzim inhibisyon potansiyellerini belirlemektir.

Materyal ve Metod

Bitki Materyali

Çalışmada kullanılan *Consolida orientalis* bitkisi Haziran-Temmuz 2023 tarihleri arasında Sivas İmaret Köyü sınırları içerisinde, 1400 m yükseklikte, 39°41'40"K, 37°02'25"D koordinatlarındaki alandan toplanmıştır. Toplanan örneklerin taksonomik tanımlaması Anadolu Üniversitesi Eczacılık Fakültesi Öğretim Üyesi Prof. Dr. Yavuz Bülent KÖSE tarafından yapılmıştır. Toplanan bitkiye ait bir örneğe herbaryum numarası ESSE:16195 verilerek etiketlenmiş ve Anadolu Üniversitesi Eczacılık Fakültesi Herbaryumu'nda kayıt altına alınarak saklanmıştır.

Ekstraksiyon Hazırlanması

Çalışmamızda *Consolida orientalis*'in çiçek kısımlarından hazırlanan bitki özütleri kullanıldı. Örnekler önce musluk suyuyla, daha sonra olası kontaminasyonu önlemek için saf suyla yıkandı, daha sonra kurutma kağıtlarında kurutuldu, öğütücüde öğütüldü ve 100 gram alınarak üzerine 1000 ml etanol eklendi. 150 rpm'de bir çalkalayıcıda oda sıcaklığında 24 saat bekletildi. Ekstraksiyon işleminin sonunda özüt filtre kağıdından süzüldü ve daha sonra çözücü 40 °C'de döner buharlaştırıcıda uzaklaştırıldı. Elde edilen özütler koyu renkli cam şişeye konularak deneysel işlemlerde kullanılmak üzere -20 °C'de saklandı (Mata et al., 2007).

Anti-tirozinaz Aktivite

C. orientalis etanol ekstresinin (20 µg/mL) in *vitro* anti-tirozinaz aktivitesi, Hearing ve Jimenez'in (Hearing & Jiménez, 1987) tasarladığı metoda göre gerçekleştirilmiştir. İlk olarak, bileşiklerin difenolaz fonksiyonunu inhibe etme yeteneği değerlendirilmiştir ve substrat olarak L-DOPA kullanılmıştır. Mantar kaynaklı tirozinaz (E.C. 1.14.18.1) (30 U, 28 nM) Na-fosfat tamponunda (pH = 6.8, 50 nM) çözülmüş ve bileşikler çözeltinin içine eklenerek oda sıcaklığında on dakika boyunca ön inkübasyona bırakılmıştır. Enzimatik reaksiyonu başlatmak için, karışıma 0.5 mM L-DOPA eklenmiştir ve 37 °C'de 475 nm'de absorbans değişimi ölçülmüştür. Pozitif kontrol olarak kojik asit kullanılmıştır (Şahin et al., 2023).

Anti-kolajenaz Aktivite

C. orientalis etanol ekstresi (20 µg/mL) başlangıçta etanol ile çözüldü. Enzim inhibisyon deneyi, "Kollajenaz Aktivite Deney Kiti (Kolorimetrik, Abcam 196999)" üreticinin talimatlarına uygun olarak gerçekleştirilmiştir. Maddelerin enzim inhibisyonu kinetik modda 37°C'de çok modlu mikroplaka okuyucu (SpectraMax i3) ile 345 nm'de ölçülmüştür. Ekstrenin enzim inhibisyonu, kitte bulunan standartlarla karşılaştırılarak hesaplanmıştır. Numuneler için ortalama değer olarak % inhibisyon değeri hesaplanmıştır. Çalışmalar üç tekrarlı olarak yapılmıştır (Şahin et al., 2023).

Bulgular ve Tartışma

Anti-tirozinaz ve Anti-kollajenaz Aktivite

C. orientalis etanol ekstraktlarının tirozinaz ve kolajenaz enzim inhibisyon kapasiteleri araştırıldı. Elde edilen sonuçlara göre, *C. orientalis* etanol ekstraktı tirozinaz enziminde %13, kolajenaz enziminde ise %23,2 oranında inhibisyon gösterdi. Kojik asit ve kersetin sırasıyla anti-tirozinaz aktivitesi ve anti-kolajenaz aktivitesi için pozitif standartlar olarak kullanıldı. Tablo 1'de *C. orientalis* etanol ekstresinin anti-tirozinaz ve anti-kollajenaz aktivitesi sonuçları yer almaktadır.

Tablo 1. *C. orientalis* etanol ekstresinin anti-tirozinaz ve anti-kollajenaz aktivitesi.

	***C. orientalis* etanol ekstresi**	**Pozitif kontrol**
	% inhibisyon	
Anti-tirozinaz aktivite	13,0	98,9 (Kojik asit)
Anti-kollajenaz aktivite	23,2	91,4 (Kersetin)

C. orientalis etanol ekstresinin anti-tirozinaz aktivitesi incelendiğinde; düşük-orta seviyede tirozinaz enzimini inhibe ettiği sonucuna varılmıştır. *C. orientalis* etanol ekstresinin anti-kollajenaz aktivitesi, mevcut çalışmada ilk kez araştırılmıştır. Sonuçlar incelendiğinde ekstrenin düşük-orta seviyede kollajenaz enzimini inhibe ettiği görülmektedir.

Cilt yaşlanması kaçınılmaz süreci nedeniyle hepimizin en çok endişe duyduğu konulardan biridir. Günlük yaşamda, cildin güneşe maruz kalması, fotoyaşlanma adı verilen erken cilt yaşlanması görünümünü hızlandıran en önemli faktör olarak kabul edilir. Fotoyaşlanma, hücrelerdeki reaktif oksijen türleri (ROS) sentezinin dışsal mekanizmasını tetikleyebilir ve ROS'un aşırı üretimi, DNA'ya zararlı olan lipid peroksidasyonuna, ardından hücre hasarına ve hücre ölümüne neden olabilir (Jiratchayamaethasakul et al., 2020). Normalde vücutta bir denge vardır: ROS üretimi ile antioksidan savunma sistemi arasında. Bu denge bozulduğunda oksidatif stres ortaya çıkar. Bitkilerden elde edilen doğal antioksidanlar bu dengeyi yeniden kurmaya yardımcı olabilir. *Consolida orientalis* çiçek ekstrelerinin antioksidan aktivite açısından DPPH ve ABTS radikal temizleme testleri incelenmiş. Tüm ekstrelerin temizleme aktivitesi gösterdiği böylelikle bitkinin antioksidan aktivitesinin olduğu sonucuna varılmıştır (Sönmez Gürer, Karadağ, Baydar, & Demirel, 2024).

2019 yılında gerçekleştirilen bir çalışmada, *Consolida orientalis*'in metanol, etil asetat ve su ekstraktlarının tirozinaz inhibitör aktiviteleri değerlendirilmiştir. Sonuçlar, metanolik ekstraktın yüksek fenolik ve flavonoid içerikleriyle önemli derecede tirozinaz inhibitör aktivite gösterdiğini ortaya koymuştur. Bu etkinlik, epidermal hiperpigmentasyonun yönetiminde potansiyel bir tedavi seçeneği sunmaktadır (Zengin et al., 2019).

Consolida orientalis'in kollajenaz inhibitör aktivitesi üzerine doğrudan bir çalışma bulunmamakla birlikte, benzer bitkiler üzerinde yapılan araştırmalar, bu tür aktivitelerin varlığını göstermektedir. Örneğin, 2020 yılında yapılan bir çalışmada, çeşitli halofit bitkilerin elastaz, kollajenaz, hiyaluronidaz ve tirozinaz inhibitör aktiviteleri

incelenmiştir. Bu tür enzim inhibitör aktiviteleri, yaşlanma karşıtı ve cilt bakım ürünlerinin geliştirilmesinde önemli hedeflerdir (Jiratchayamaethasakul et al., 2020).

Tartışma ve Sonuç

Consolida orientalis bitkisi, özellikle metanolik ekstraktlarıyla tirozinaz inhibitör aktivite göstererek epidermal hiperpigmentasyonun yönetiminde potansiyel bir kaynak olarak değerlendirilebilir. Kollajenaz inhibitör aktiviteleri üzerine daha fazla araştırma yapılması, bu bitkinin yaşlanma karşıtı ve cilt bakım ürünlerinde kullanımını daha da destekleyecektir. Bu bağlamda, *Consolida orientalis*'in kozmetik ve farmasötik alanlarda kullanım potansiyelini değerlendiren daha kapsamlı in vitro ve in vivo çalışmalar önerilmektedir.

Kozmetik sektörü özellikle cilt yaşlanmasında önemli büyüme göstermektedir. Bu nedenle yaşlanmayı ve pigmentasyonu önleyen doğal ürünlerle ilgili çalışmaların popüler araştırma alanları olduğu bilinmektedir. Çalışmamızda; ciltte melanin pigmentinin farklılaşmasıyla oluşan dermatolojik hastalıklarda, nörolojik hastalıklarda ve anti-tirozinaz aktivite testi ile gıda/kozmetik sektöründe kullanılıp kullanılamayacağının tanımlanması; anti-kollajenaz aktivite testi ile kırışıklık ve cilt yaşlanması karşıtı hazırlanan topikal formülasyonların içeriğinde kullanılıp kullanılamayacağının belirlenmesi hedeflenmiştir. Sonuçlara göre *Consolida orientalis*'in düşük-orta seviyede anti-kollajenaz ve anti-tirozinaz aktivitesine sahip olduğu bulunmuştur. *C. orientalis*'in, hiperpigmentasyon ve cilt yaşlanmasının yönetimi için bitki kaynaklı ürünlerin geliştirilmesinde aday olarak kabul edilebilir ve bu konuda daha fazla çalışma yapılması gerekir. Bildiğimiz kadarıyla bu çalışma, *C. orientalis*'in anti-kolajenaz inhibitör etkilerini araştıran Türkiye'den ilk rapor olarak kabul edilebilir.

Bu sonuçlar bize; *C. orientalis* bitkisine ait çiçeklerin tirozinaz ve kollajenaz enzimini inhibe etme potansiyellerinin yüksek seviyede olmasa da varolduğunu göstermiştir. *C. orientalis* daha fazla çalışmayı hak eden, hiperpigmentasyon ve cilt yaşlanması yönetimine yönelik bitki kaynaklı ürün geliştirilmesi için yeni bir aday olarak değerlendirilebilir.

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Disease Prediction in Poultry Using Artificial Intelligence Tools

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Abstract

Poultry farming has become a vital component of human nutrition worldwide, growing alongside industrial production. Despite its scale reaching millions of tons annually infectious diseases remain a major challenge. Each year, millions of chickens reportedly die due to these outbreaks, causing significant economic losses and disrupting flock health. Traditional methods often fall short in early detection and control, making timely intervention difficult. Recent technological advancements have opened new possibilities in poultry health management. Artificial Intelligence (AI), in particular, has emerged as a promising solution in a sector that is otherwise hard to monitor effectively. AI technologies, mainly categorized into Machine Learning (ML) and Deep Learning (DL), enable the analysis and interpretation of large, complex datasets. Using AI-based models, researchers can analyze both collective and individual behaviors, along with biological data, to identify early signs of disease often before visible symptoms occur. Studies have shown that ML algorithms such as Support Vector Machine (SVM) and Random Forest can achieve accuracy rates exceeding 90%. Meanwhile, DL models like Convolutional Neural Networks (CNN) and Long Short-Term Memory (LSTM) networks have demonstrated predictive accuracy as high as 94–98%. These systems help producers identify not just diseases but also potential pathogens at early stages, significantly minimizing animal losses and enhancing biosecurity. However, for widespread adoption, challenges like data quality, implementation cost, and farmer training need to be addressed. In conclusion, AI-powered disease prediction tools represent an innovative and impactful development in the poultry industry. By improving early detection, reducing economic losses, and enhancing operational efficiency, they are expected to play a crucial role in shaping the future of sustainable, technology-driven livestock production.

Key Words: *Machine Learning, Deep Learning, Agriculture 4.0, Poultry Disease Prediction, Artifical Intelligence (AI)*

Tavuklarda Yapay Zekâ Araçları ile Hastalık Tahmini

Özet

Tavukçuluk, endüstriyel üretimin büyümesi ve gelişmesiyle dünya genelinde insan beslenmesinin vazgeçilmez bir parçası halini almıştır. Yılda milyonlarca ton hacim olan bu sektörün en büyük sorunlarından biri, bulaşıcı hastalıklardır. Bu hastalıklar yüzünden her yıl milyonlarca tavuğun öldüğü bildirilmiştir. Bu durum üreticilerin ciddi ekonomik kayıplarının yanı sıra sürü sağlığının kontrol edilemez boyutlara ulaşmasına neden olmuştur. Sürü içerisindeki hastalıkların zamanında teşhis edilip gerekli önlemlerin alınması ne yazık ki geleneksel yöntemler ile oldukça zor olmaktadır. Son yıllardaki teknolojik gelişmelerin ivmelenerek artması bu alandaki çalışmaları destekleyerek uygulama noktalarını arttırmıştır. Bu teknolojik gelişmelerin başında olan yapay zekâ uygulamaları, başta takibi oldukça zor olan tavukçuluk sektörünün pozitif yönde ilerlemesine yardımcı olmuştur. Bu teknoloji, Makine öğrenimi ve Derin öğrenme olarak iki temel birime ayrılarak büyük ve karmaşık verilerin işlenerek anlam kazandırılmasını sağlamaktadır. Yapay zekâ yöntemlerinin geliştirdiği modeller sayesinde, tavukların hem sürü içerisindeki hem de bireysel davranışlarının ve biyolojik verilerini analiz ederek hastalık semptomları başlamadan tespit edebilmesine olanak sağlamaktadır. Yapılan çalışmalarda SVM (Support Vector Machine), Random Forest gibi Makine öğrenimi algoritmalarının yaklaşık %90' ın üzerinde doğruluk oranlarına, CNN (Convolutional Neural Network) ve LSTM (Long Short-Term Memory) gibi algoritmaların ise %94-98' e varan başarıya ulaştığı tespit edilmiştir. Endüstriyel üretimde kullanılan bu sistemler sayesinde üreticiler, hastalıkları hatta hastalık etmenlerini erkenden fark ederek hayvan kayıplarını ciddi oranda azaltmakta ve biyo-güvenllik seviyesinin yükseltilmesine olanak sağlamaktadır. Bu teknolojik gelişmenin saha da daha yaygın kullanılması için veri kalitesinin arttırılması maliyetlerin düşürülmesi ve çiftçiyi entegre edebilmek için gerekli eğitimlerin verilmesi gerekmektedir. Sonuç olarak, yapay zekâ algoritmaları tavukçuluk sektörü için biyo-güvenliği arttıran, ekonomik kayıpları azaltan ve verimliliği arttıran yenilikçi bir çözüm sunmaktadır. Geleceğin sürdürülebilir ve teknoloji destekli hayvancılık modelini oluşturacak en önemli gelişme olarak görülmektedir.

Anahtar Kelimeler: *Makine Öğrenimi, Derin Öğrenme, Tarım 4.0, Kanatlılarda Hastalık Tahmini, Yapay Zeka (YZ)*

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Probiotic and Paraprobiotic Fermented Milk Enriched with Jujube and Pumpkin Fruits

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Abstract

This study evaluated the effects of jujube and pumpkin supplementation on the microbiological, physicochemical, textural, and sensory properties of probiotic and paraprobiotic fermented milk. *Lacticaseibacillus rhamnosus* and yogurt cultures were used for fermentation, and paraprobiotic samples were obtained post-fermentation heat treatment (85 °C, 20 min). Viable counts of *Streptococcus thermophilus* and *Lactobacillus bulgaricus* + *L. rhamnosus* declined during storage in probiotic samples, while low but detectable levels persisted in paraprobiotic ones, indicating incomplete inactivation. Jujube supplementation showed a relatively stabilizing effect on *S. thermophilus* counts by Day 24. Paraprobiotic samples exhibited higher pH and lower acidification due to reduced microbial activity. Viscosity was consistently lower in paraprobiotic samples compared to probiotic ones, and fruit addition slightly reduced viscosity in probiotic formulations. Both hardness and adhesive force were lower in paraprobiotic samples at the beginning and end of storage, although both increased over time. It was determined that brightness and whiteness values were lower in samples containing paraprobiotics and fruit, and decreased in all samples during storage. Fruit-enriched paraprobiotic samples exhibited the lowest serum separation, suggesting improved phase stability. In sensory analyses, especially for taste, control and jujube-supplemented probiotic samples scored particularly high. Although fruit addition enhanced sweetness perception across all samples, it did not improve overall taste acceptance. Paraprobiotic samples, especially those with pumpkin, received the lowest sensory scores. In summary, fruit supplementation and thermal treatment jointly affected the structural and sensory characteristics of fermented milk. While some physical parameters improved in paraprobiotic formulations, sensory attributes remained higher in probiotic samples. These findings provide insight into the challenges of balancing functionality and consumer appeal and may guide future work on optimizing fruit incorporation and processing methods in fermented dairy systems.

Key Words: *Probiotic, Paraprobiotic, Jujube, Pumpkin, Fermented Milk*

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Determination of Yield and Quality Characteristics of Patchouli (*Pogostemon cablin*) Plant in Çukurova Conditions

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Abstract

Patchouli is a valuable plant, which is traded in the world and whose essential oil is important in terms of its therapeutic properties and widely used in the perfumery industry. In this study was determined the yield and quality characteristics of patchouli (*Pogostemon cablin* (Blanco) Benth.) plant in Çukurova conditions. In the research, harvest were made in 3 different periods: before flowering, full flowering and after flowering. As a result of the research, the highest plant height (47.39 cm) after flowering, number of branches (16.13 units), fresh herb yield (2106.78 kg/da), fresh leaf yield (1022.36 kg/da), dry herb yield (458.74 kg/da) and dry leaf yield (209.88 kg/da) was obtained during the full flowering period. The highest essential oil yield (1.77%) was obtained before flowering and the essential oil yield (207.36 kg/da) was obtained during the full flowering period. The main components of essential oil are Acetophenone %41.56, Patchouli alcohol %28.30, trans-Nerolidol %17.17, while other components are Caryophyllene %8.71, α-Guaiene %5.86, Seychellene %4.84, α-Bulnesene %2.53, Pogostole %1.24 respectively, which were characterised by GC/MS (+/-0.5, n=3).
Keywords: *Pogostemon cablin, Patchouli, yield, essential oil content, patchouli alcohol*

Çukurova Koşullarında Paçuli (*Pogostemon cablin*) Bitkisinin Verim ve Kalite Özelliklerinin Belirlenmesi

Özet

Paçuli, dünyada ticareti yapılan ve uçucu yağı değerli olan hem terapötik özellikleri bakımından önemli hem de parfümeri sektöründe çokça kullanılan bir bitkidir. Bu araştırma; Paçuli (*Pogostemon cablin* (Blanco) Benth.) bitkisinin Çukurova koşullarında verim ve kalite özelliklerinin belirlenmesi amacıyla yapılmıştır. Araştırmada çiçeklenme öncesi, tam çiçeklenme ve çiçeklenme sonrası olmak üzere 3 farklı dönemde biçimler yapılmıştır. Araştırma sonucunda en yüksek bitki boyu (47.39 cm) çiçeklenme sonrası, dal sayısı (16.13 adet), taze toprak üstü verimi (2106.78 kg/da), taze yaprak verimi (1022.36 kg/da), kuru toprak üstü verimi (458,74 kg/da) ve kuru yaprak verimi (209.88 kg/da) ise tam çiçeklenme dönemde yapılan biçimden elde edilmiştir. En yüksek uçucu yağ oranı (%1.77) çiçeklenme öncesi dönemde ve uçucu yağ verimi (2.07 l/da) ise tam çiçeklenme döneminde yapılan biçimden elde edilmiştir. Uçucu yağın ana bileşenlerini Asetofenon %41.56, Patçuli alkol %28.30, trans-Nerolidol %17.17 oluştururken diğer bileşenler ise Karyofilen %8.71, α-Guaien %5.86, Seyşellen %4.84, α-Bulnesen %2.53, Pogostol %1.24 olarak GC/MS (+/-0.5, n=3) ile tespit edilmiştir.

Anahtar Kelimeler: *Pogostemon cablin, paçuli, verim, uçucu yağ oranı, patçuli alkol*

Giriş

Tıbbi ve aromatik bitkiler eski çağlardan beri ilaç, gıda, parfümeri ve kozmetik gibi farklı alanlarda kullanılmaktadır (Tulukçu ve Sağdıç, 2011).Bu bitkilerin çoğu tedavi amaçlı kullanılmakta olup, önemli bir kısmı doğadan toplanmakta ve bir kısmının da kültürü yapılmaktadır. Tıbbi ve aromatik bitkilere olan ilginin artmasına paralel olarak bu bitkiler üzerine araştırmalar artmış, bunun sonucunda yetiştiricilik ve ıslah çalışmaları sonucu pek çok bitki türü kültüre alınarak, üstün hatlar elde edilmiştir (Ceylan ve ark. 1991).

Lamiaceae (Labiatae) familyası; gıda, ilaç ve kozmetik endüstrisi için önemli uçucu yağ içeriğine sahip tıbbi ve aromatik bitkileri ile ünlüdür. Bu bitkilerin uçucu yağları ve özlerinin antiseptik, antiinflamatuar ve antimikrobiyal aktivitelere sahip olduğu bilinmektedir (Hussain ve ark. 2011; Theodoridis ve ark, 2012). Türkiye de *Lamiaceae* familyası en zengin üçüncü familya olup, önemli bir gen merkezi konumundadır ve endemizm oranı % 44.2'dir (Başer, 1993, Kocabaş ve Karaman 2001).

Bu familyaya ait mistik bir kokusu olan, Paçuli adı ile bilinen bitki '*Pogostemon cablin* benth' bu türlerden biridir. Paçuli ismi 'yeşil yaprak' olarak bilinen Pacchilai (tamilce) kelimesinden gelmekte ve ilk olarak 1845'te Filipinler'deki botanikçiler tarafından tanımlanmıştır. Paçuli; ülkemizde Tefarük olarak adlandırılır (Anonim, 2021). Bu bitki tüm dünyada yetiştirilse de esas olarak Güney Doğu Asya ülkelerinde yabani olarak yetişir. Endonezya, Çin, Hindistan, Malezya, Tayland, Vietnam, Filipinler'de yaygın olarak yetiştirilmektedir (Maheshari

ve ark., 1993; Chakrapani ve ark.,2013). Bitkinin yaprakları, baskın aromatik baharatlı kokusu nedeniyle parfümeride ve aromaterapide oldukça değerli olan uçucu yağa sahiptir (Hasegawa ve ark., 1992). Bitkilerde ikinci metobolizma ürünü olan uçucu yağlar; bulundukları yerin iklim, toprak kompozisyonu, coğrafik bölge, yetişme sezonu boyunca toprak nem içeriği gibi çevresel faktörlerin yanı sıra bitkinin yaşına ve gelişme dönemine, kullanılan organına ve hatta hasat saatine göre kalite, miktar ve bileşimde değişiklik gösterebilmektedir (Kırıcı & İnan, 2001; Giray ve ark., 2008; Kaya ve ark., 2012; Maral ve ark., 2018; Maral & Kırıcı, 2019; Çalışkan ve ark. 2019).

Paçuli yağının zengin misk-tatlı, güçlü baharatlı ve otsu bir kokusu vardır. Şimdiye kadar elde edilen en yüksek uçucu yağ oranı %2.6 civarındadır ve yüksek viskoziteli olup, genellikle açık sarı ile koyu kahverengi arasında değişen renklere sahiptir (Bhatti ve Ingrouille 1997; Safarudin ve ark., 2018). Paçuli yağı, içerdiği bileşenler sayesinde afrodizyak etkiye sahip olup, depresyonu ve kaygıyı hafifletmek, sinirleri yatıştırmak için aromaterapide yaygın olarak kullanılmaktadır. Ayrıca yapılan çalışmalar sonucunda paçuli yağı terapötik olarak antimikrobiyal, antienflamatuvar, antioksidan, antidepresan, anti-emetik, analjezik ve sitotoksik özelliklere sahiptir (Chakrapani ve ark., 2013; Priya ve ark., 2014; Swamy ve Sinniah, 2016). Paçuli yağının diğer bir kullanımı; koku endüstrisinde güçlü bir baz görevinde olup, uçucu moleküllerin buharlaşmasını önleyerek kokunun kalıcılığını arttırmasıdır. Bu nedenle günümüzde sabunlar, deterjanlar, vücut losyonları ve parfümler gibi çeşitli sağlık bakım ürünlerinin içeriklerinde yer almaktadır (Murugan ve Livingstone, 2010; Swamy ve Sinniah, 2016). Bu karakteristik özellikler, paçuli bitkisinin dünya çapında çeşitli uygulamalar için büyük endüstriyel öneme sahip ticari bir ürün olarak değerlendirilmesini sağlar. Paçuli, dünyada ticareti yapılan ve uçucu yağı değerli olan ilk 20 bitkiden biridir (Lubbe and Verpoorte, 2011; Singh ve ark., 2015). Paçuli toplam pazarı 2022 yılında 82,39 milyon USD olup, yıllık bileşik büyüme oranı (CAGR) %3,9 olup, 2028 yılında 103,62 milyon USD olması beklenmektedir (Anonim, 2023).

Bu çalışmanın amacı; daha önce bu bölgede yetiştirilmeyen, değerli uçucu yağa sahip olan Paçuli (*Pogostemon cablin*) bitkisinin Çukurova koşullarında yetiştiriciliğinin araştırılarak uygun hasat zamanı ve verim gibi özelliklerinin belirlenmesidir.

Materyal ve Yöntem

Paçuli (*Pogostemon cablin*), Lamiaceae familyasına ait *Pogostemon* cinsinin 25 türünden biridir. Filipinlere özgü olan bitki ve Güneydoğu Asya ülkelerinin çoğunda yetişmektedir. Ortalama deniz seviyesinden 800-1000m yüksekliğe kadar yetişebilen, yılda 1.500 mm ila 3.000 mm arasında yağış alan, subtropikal koşullara uygun bir bitkidir (Ramya ve ark., 2013; Swamy ve Sinniah, 2016). Yıl boyunca nemin %70-90 civarlarında ve sıcaklığın 22-28°C olduğu iklim koşullarıyla; iyi drene edilmiş humusça zengin, verimli, pH'ı 5.5-6.2 olan topraklarda ve periyodik sulama altında iyi gelişim gösterir (Bhaskar 1995). Bitki yaklaşık 1.0-1.5 m yüksekliğe kadar büyür. Yapraklar yaklaşık 7-10 cm uzunluğunda, oval, epidermisin her yerinde trikomlarla kaplı ve tam güneş ışığında değişken yeşil, ancak gölgede parlak yeşil renktedir. Çiçekler küçük, narindir ve hem koltuk altı hem de uç dikenlerde bulunur. Genelde pembemsi renktedirler. Tohumlar doğada oldukça kırılgandır. Çiçekler sonbahar mevsiminde çiçek açar (Das, 2016). Uçucu yağ kök dahil olmak üzere bütün kısımlarda bulunurken yapılan araştırmalara göre üst yapraklar ve ince dallar en kaliteli uçucu yağı vermektedir (Vijyakumar 2004). Paçuli yağı; güçlü baharatlı, otsu kokuya sahip zengin ve uzun ömürlüdür. Şarap gibi yıllandıkça yağın kalitesi daha gelişir ve yağ eskidikçe önemli ölçüde yumuşar, daha tatlı ve balzamik bir aroma alır (Ramya ve ark.2013)

Çukurova koşullarında paçuli (*P. cablin*) bitkisinden yüksek toprak üstü verimi ve uçucu yağ oranı alınabileceği uygun biçim zamanlarının belirlenmesi amacıyla yapılan bu çalışma 2022 üretim sezonunda Çukurova Üniversitesi Ziraat Fakültesi Tarla Bitkileri Araştırma ve Uygulama Arazisinde, tesadüf blokları deneme deseninde 3 tekerrürlü olarak kurulmuştur. Çalışma materyali fide şeklinde ticari bir firmadan temin edilmiştir. Hasat zamanları olarak çiçeklenme öncesi, tam çiçeklenme ve çiçeklenme sonrası dönemler olmak üzere 3 farklı gelişme dönemleri seçilmiştir.

Çukurova Bölgesi Akdeniz iklim kuşağı etkili olduğundan kış dönemi ılıman ve yağışlı, yaz dönemi oldukça sıcak ve kurak geçmektedir. Bitkilerin araziye şaşırtma işleminin gerçekleştiği Nisan ayında (12 Nisan 2022) ortalama sıcaklık 20 ˚C, ilk biçimin yapıldığı Ağustos ayında (21 Ağustos) ortalama sıcaklık 29.5 ˚C ; ikinci biçimin yapıldığı Kasım ayında (19 Kasım) ise ortalama sıcaklık değeri 17.8˚C, üçüncü biçimin yapıldığı Aralık ayında ise (28 Aralık) ortalama 13.9 ˚C sıcaklıktır (DMİ, 2022). Çalışmanın yapıldığı alandaki topraklar düz ve düze yakın topografyadan oluşup Seyhan Nehri'nin yan derelerinin getirdiği genç alüvyal yapıya sahiptir, çeşitli derinliklerde çakıl depozitleri bulunduran, bütün profilde kireç miktarı oldukça yüksek ve organik madde miktarı bakımından da oldukça düşük topraklardır (Özbek ve ark. 1974). Toprağın pH değeri 7.68 olup, genellikle hafif alkali bir özellik göstermektedir. Toprağın P_2O_5 içeriği 14.2 kg/da K_2O içeriği ise 91.5 kg/da olarak bulunmuştur. Toprağın kireç içeriği %32.4 olarak belirlenmiştir

Toprak hazırlığı yapılan alanda, araştırma; her parsel 4.2 x 6,4= 26,88 m², toplam deneme parsel alanı ise 14 x 6,4= 89,6 m² olacak şekilde tesadüf blokları deneme desenine göre üç tekrarlamalı olarak kurulmuştur. Parseller 7 sıradan oluşmuş olup, her parsel 70 bitkiden oluşacak şekilde, toplam 210 bitki, sıra üzeri mesafe 70 cm, sıra arası mesafe 70 cm olacak şekilde ayarlanmıştır. Fideler 12 Nisan 2022'de deneme alanına şaşırtılmıştır .Ardından

deneme alanı sulanmıştır. 22 Nisan 2022'de İnorganik gübre olarak, kompoze gübre (15.15.15) saf azot hesabıyla (2 kg/da) dikimden sonra uygulanmıştır. Her bir biçimden sonra 20.20.0 kompoze gübresinden saf madde üzerinden 2 kg/da olacak şekilde üst gübre verilmiştir. Deneme alanı dikimden sonra 2 hafta boyunca 3 günde bir, sonrasında ise her hafta düzenli olarak yağmurlama şeklinde sulama yapılmıştır. Adana'da havaların ısınmasıyla beraber güneşten direkt etkilenmemesi için de bitkilerin üzerine gölgelik yapılmıştır.
Araştırmada 3 farklı dönemde biçim yapılmıştır. İlk biçim 21 Ağustos 2022 tarihinde çiçeklenme öncesi dönemde yapılmıştır. Bitkilerde ilk çiçek 12 Kasım'da gözlenmiş olup tam çiçeklenme biçimi 19 Kasım 'da yapılmıştır. Bitkiler bir süre çiçekli kalmış olup son biçim 28 Aralık 2022 tarihinde çiçeklenme sonrası dönemde yapılmıştır. Bitkiler toprak yüzeyinden 5 cm yukarıdan hasat edilmiştir. Her hasat sonrası bitkiler tartılarak yaş herba ağırlıkları saptanmıştır. Daha sonra sap ve yaprak ayrımı yapılıp oda sıcaklığı koşullarında gölgede kurumaya bırakılmıştır. Kurutulan droglar tartılıp gerekli tekrar ve biçim bilgileri yazılan uygun kese kağıtlarına konmuş ve uçucu yağ kaybını önlemek amacıyla ağızları kapatılmıştır. Clevenger apareyi kullanılarak hidro- distilasyon yöntemiyle uçucu yağ analizi yapılmıştır. Uçucu yağ örnekleri derin dondurucuda muhafaza edilerek tüm hasatlar tamamlandıktan sonra uçucu yağın bileşenleri GC/MS ile Ç. Ü. Merkez Araştırma Laboratuvarında saptanmıştır. Uçucu bileşen analizi Agilent Marka 7890B GC, 7010B MS cihaz ile belirlenmiştir. Örnekler 100 kat olacak şekilde DCM (diklorametan) ile seyreltilmiştir. Analizde DB-Wax (60 m x 0.25 mm i.dx 0.25 µm, J&W Scientific-Folsom, USA) kapiler kolonuna 1 uL örnek enjekte edilmiştir. Enjeksiyon sıcaklığı 250 °C, kolon sıcaklığı 100 °C de başlayıp, sonra dakikada 3 °C artırılarak 180 °C'ye, sonra dakikada 10 °C artırılarak sıcaklık 240 °C'ye ayarlanmış ve bu sıcaklıkta 3 dakika bekletilmiştir. Taşıyıcı gaz He kullanılmıştır. Elektron enerjisi 70 eV ve kütle aralığı ise 30-600 *m/z*'dir. Kütüphane olarak NIST14L kullanılmıştır.
Araştırmada elde edilen veriler JMP istatistik analiz programı kullanılmış, incelenen özellikler arasında farklılıklar %5 ve %1 önem düzeyine göre ANOVA analizi yapılarak EGF testine göre belirlenmiştir.

Bulgular ve Tartışma

Çukurova bölgesinde ilk defa yetiştirilen *P. cablin*'de farklı gelişme dönemlerinde verim, uçucu yağ ve uçucu yağ bileşenlerinin belirlenmesi amacıyla yapılan bu araştırmada elde edilen veriler aşağıda değerlendirilerek tartışılmıştır.

Morfolojik Özellikler

P. cablin bitkisinde bitki boyu ve dal sayısı üzerine yapılan varyans analizi sonucuna göre biçim zamanlarınına %1 düzeyinde etkili olduğu saptanmıştır (Çizelge 1). *P. cablin* bitki boyu değerleri ortalama 29.03- 47.39 cm arasında değişmiş olup, dal sayısı bitki başına 11-16.13 adet arasında olmuştur. Tam çiçeklenme ve çiçeklenme sonrası dönemde biçilen bitkilerin bitki boyu değerleri ve dal sayıları arasında istatiksel olarak önemli bir fark saptanamamıştır. Bu durum bitkinin generatif döneme kadar gelişmesini devam ettirdiği, çiçeklenmeden sonra boyuna büyümenin yavaşladığını göstermektedir.

Çizelge 1. *Pogostemon cablin* bitkisinde farklı biçim zamanlarında elde edilen ortalama bitki boyu (cm) ve dal sayısı (adet/bitki) değerleri

Biçim Zamanı	***Bitki Boyu (cm)***	***Dal Sayısı (adet/bitki)***
Çiçeklenme Öncesi	29.03 **B***	11.00 **B***
Tam Çiçeklenme	44.16 **A**	16.13 **A**
Çiçeklenme Sonrası	47.39 **A**	16.10 **A**
EGF(%5)	8.26	2.56

*:Aynı harfler ile gösterilenler arasında fark yoktur. ö.d: istatistiksel olarak anlamlı değil

P. cablin bitkisi ile yapılan çeşitli araştırmalarda bitki boyunun 31cm- 118.03 cm arasında değişen farklı sonuçlar alınmıştır (Singh ve Ganesha Rao, 2009; Singh, 2011; Saha ve ark., 2014; Swamy ve Sinniah, 2016; Soibam ve ark., 2022). Bitki boyu özelliği bakımından literatürler verilerine göre bitki boyu değerleri bazı araştırıcıların sonuçları ile benzer ve düşük olmuştur. Swamy ve Sinniah (2016)'e göre *P. cablin* bitkisine ait dal sayılarını en yüksek 37.3, en düşük 25.8 adet olduğunu, Saha ve ark., (2014)'da 140 kg N/ha ile birincil dal sayısını 4.9 adet, Soibam ve ark. (2022) araştırmalarında ise farklı gübre uygulamaları ile en yüksek dal sayısını 7.8 adet olarak belirtmişlerdir. Bu araştırma sonucunda elde edilen dal sayısı Soibam ve ark. (2022), Saha ve ark (2014)'e göre daha yüksek, ancak Swamy ve Sinniah, (2016)'den daha düşük bulunmuştur. Bu durum ekolojik koşullar ve gübreleme gibi yetiştirme teknikleri farklılıklarından kaynaklanmaktadır.

Verim Değerleri

P. cablin bitkisinde farklı biçim zamanlarında elde edilen taze ve kuru herba verimlerine ait değerler arasında varyans analizi sonucunda %5 düzeyinde önemli farklılık olduğu saptanmıştır (Çizelge 2). Bitkide taze herba verimi en düşük olarak 976.99 kg/da ile çiçeklenme öncesi dönemde yapılan biçimden elde edilirken en yüksek değer 2106.78 kg/da ile tam çiçeklenme döneminde yapılan biçimden elde edilmiştir. Tam çiçeklenme ile çiçeklenme sonrası elde edilen taze toprak üstü verimi değerleri arasında istatiksel olarak önemli bir fark

bulunmamıştır. Paçuli bitkisinde de taze herba verimi konusunda yapılan araştırmalarda 1485-2388 kg/da veri elde edilmiştir (Singh ve Ganesha Rao, 2009; Singh, 2011) Taze herba verimi ile elde edilen değerler ile benzer ve düşük olmuştur, bu durum ekolojik koşulların ve yetiştirme tekniklerinin farklılıklarından kaynaklanmaktadır. Kuru herba verim değeri taze herbanın kurutulması sonucu elde edilen değerdir. Kuru herba verimlerinde en düşük 118.82 kg/da ile çiçeklenme öncesi dönemde yapılan biçimden elde edilirken kuru toprak üstü verimi en yüksek değeri 458.74 kg/da ile tam çiçeklenme döneminde yapılan biçimden elde edilmiştir (Çizelge 2).

Çizelge 2. *Pogostemon cablin* bitkisinde farklı biçim zamanlarında elde edilen ortalama verim(kg/da) ve uçucu yağ oranı(%) değerleri

Biçim Zamanı	*Taze Herba Verimi (kg/da)*	*Kuru Herba Verimi (kg/da)*	*Taze Yaprak Verimi (kg/da)*	*Kuru Yaprak Verimi (kg/da)*	*Uçucu Yağ Oranı (%)*	Uçucu Yağ Verimi (l/da)
Çiçeklenme Öncesi	976.99 B*	118.82 B*	656.88	76.99	1.77 A*	1.36
Tam Çiçeklenme	2106.78 A	458.74 A	1022.36	209.88	0.98 B	2.07
Çiçeklenme Sonrası	1467.87 AB	361.82 A	987.21	199.79	0.96 B	1.93
EGF(%5)	847.32	199.34	ÖD	ÖD	0.28	ÖD

*:Aynı harfler ile gösterilenler arasında fark yoktur. ö.d: istatistiksel olarak anlamlı değil

Taze herba veriminde olduğu gibi kuru herba verimlerinde de tam çiçeklenme ile çiçeklenme sonrası elde edilen değerler arasında istatiksel olarak önemli bir farklılık bulunmamıştır. Araştırıcılar paçuli bitkisinde kuru herba veriminin 162-564.92 kg/da arasında değiştiğini belirtmektedirler (Saha ve ark., 2014; Soibam ve ark., 2022). Burada elde edilen bulgular düşük ve benzer olmuştur. Bunun nedeni farklı kültürel uygulamalar ve ekolojik koşullardan kaynaklanmaktadır. Araştırmada paçuli bitkisinin tam çiçeklenmeye kadar geliştiği ve daha sonra vejetatif olarak fazla gelişmediği, çiçeklenme sonrası dönemde ise alt yapraklarını döktüğü için verim değerlerinin daha düşük olduğu söylenebilir. Genel olarak bitkinin çiçeklenme döneminden sonraki döneme gidildikçe fizyolojik yaşlanma ve yaprak kayıpları ortaya çıkmaktadır. Bitki boyunun uzamasıyla bitkinin alt kısımlarının ışık ve havadan yeterince yararlanamaması ve yaşlı yapraklarda bulunan azotun genç yapraklara taşınması ve alt yaprakların dökülmesine neden olmuştur (Taiz & Zeiger, 2008)

Farklı biçim zamanlarında elde edilen taze yaprak verimi ve kuru yaprak verimine ait değerler istatiksel yönden önemli bulunmamakla birlikte en yüksek değerler tam çiçeklenme döneminden elde edilmiş, ikinci sırada ise çiçeklenme sonrası yapılan biçim değerleri yer almıştır (Çizelge 2). Paçuli bitkisinin çiçeklenme öncesi dönemde daha narin ve su oranının yüksek kuru madde oranının düşük olduğu, tam çiçeklenmeye kadar geliştiği, daha sonra vejetatif olarak çok gelişmediği, çiçeklenme sonrası dönemde ise alt yapraklarını döktüğü için verim değerlerinin daha düşük olduğu söylenebilir. Yapılan çalışmalardaki verim farklılıkların nedeni araştırma yerinin, kültürel işlemlerin, iklim koşullarının farklılık göstermesinden kaynaklanmaktadır (Maral & Kırıcı 2023; Yıldırım ve ark., 2024).

Uçucu Yağ Oranı ve Bileşenleri

Paçuli bitkisinin uçucu yağ oranı üzerine biçim zamanlarını etkisi istatistiksel olarak %1 düzeyinde önemli bulunmuştur. En yüksek uçucu yağ oranı %1.77 ile çiçeklenme öncesi dönemde yapılan biçimden elde edilmiştir (Çizelge 2). Tam çiçeklenme ile çiçeklenme sonrası elde edilen uçucu yağ oranı arasında istatiksel olarak önemli bir fark bulunmamıştır.

Pandey ve ark. (2020) çeşitli sıcaklık aralıklarıyla kurutma yaptıkları paçuli bitkisinin uçucu yağ oranını %1.40 - 2.80 aralığında belirtmişlerdir. Saha ve ark. (2014) Hindistan'ın Kuzey Doğu Himalaya Bölgesi'ndeki paçulinin uçucu yağ oranın %1.88-1.93 aralığında bulmuşlardır. Singh (2011) yaptığı araştırmada en yüksek uçucu yağ oranını %3.14 olarak elde etmiştir. Shah ve ark. (2017) ise en yüksek uçucu yağ oranı %1.53 elde etmişlerdir. Yapılan araştırmalar incelendiğinde bulgular Pandey ve ark. (2020), Saha ve ark. (2014) ile benzerlik gösterirken, Singh (2011)'in değerlerinden düşük; Shah ve ark. (2017), sonuçlarına göre yüksek çıkmıştır. Araştırmada elde edilen uçucu yağ oranları ile literatürde verilen değerler benzer olmakla birlikte bazılarından düşük, bazılarında ise yüksek olmuştur. Bu durumun nedeni tıbbi ve aromatik bitkilerin uçucu yağ oranı üzerine genotip faktörünün yanında, ekolojik koşullar, yapılan kültürel uygulama farklılıkları, hasat zamanı, farklı kurutma yöntemleri gibi çeşitli unsurların etkisi olmasıdır (Kaya ve ark., 2012; Çalışkan ve ark., 2017; Oğuz & Kaplan 2023; Chandel ve ark., 2024; Dobhal ve ark., 2024). Birim alandan elde edilen verim değeri ile uçucu yağ oranı sonucu elde edilen uçucu yağ verimi üzerine farklı biçim zamanlarının etkisi istatistiksel olarak önemli bulunmamıştır (Çizelge 2). Tam çiçeklenme dönemi elde edilen 2.07 l/da olan uçucu yağ verimi ilk sırada yer almıştır. Saha ve ark. (2014) yaptıkları çalışma da bitkiye uyguladıkları farklı miktardaki N sonucunda elde edilen en yüksek uçucu yağ verimi 3.13 kg/da bulurken, en düşük 1.83 kg/da saptamışlardır. Çalışmada elde edilen veriler ile yapılan çalışmalar arasında kısmi benzerlik göstermektedir. Güneş ve gölge koşulları, toprak heterojenliği, bitki materyalinin kalitesi

ve yetiştirme uygulamalarındaki farklılıklar gibi çeşitli doğal veya kontrol edilebilir faktörler uçucu yağın verimini, karakterini ve kalitesini etkilemektedir (Bure ve Sellier, 2004).

Çalışmada incelenen uçucu yağlarda 39 bileşen belirlenmiştir. Çizelge 3 incelendiğinde uçucu yağın ana bileşenlerinin Asetofenon, Patçuli alkol, trans-Nerolidol; diğer bileşenlerin ise α-Bulnesen, α- Guaien, Karyofilen , Pogostol, Seyşellen olduğu ve bu bileşenlerin oranlarının bitkinin biçim zamanına göre değişim gösterdiği anlaşılmaktadır. Uçucu yağ bileşenlerine bakıldığında Asetofenon, hem % 41.56 ile çiçeklenme öncesi dönemde yapılan biçimde, hem de % 33.26 ile tam çiçeklenme dönemindeki biçimde en yüksek bulunurken, çiçeklenme sonrası dönemde yapılan biçimde ise uçucu yağ bileşeni en yüksek % 28.30 ile Patçuli alkol olduğu saptanmıştır.

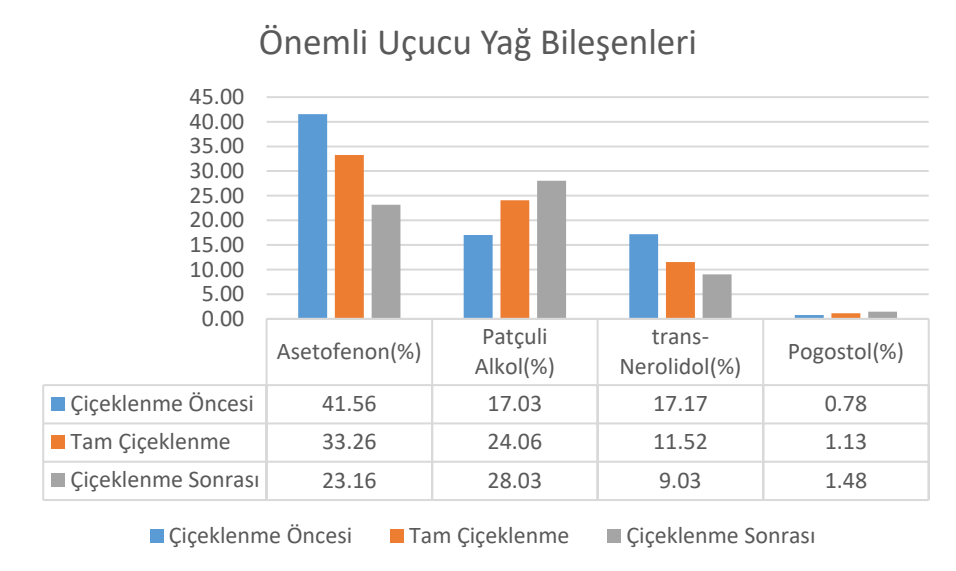
Çizelge 3. Biçim Zamanlarına göre *Pogostemon cablin* bitkisinin uçucu yağ bileşenleri

Uçucu Yağ Bileşenleri	RT	Çiçeklenme öncesi	Tam Çiçeklenme	Çiçeklenme sonrası
β-Patchoulene	13,765	0.77	0.93	1.34
Linalool	14,149	0.08	0.08	0.10
Pinocarvone	15,748	0.12	0.19	0.21
Nopinone	16,141	-	-	0.06
Cycloseychellene	16,356	0.10	0.15	0.18
Terpinen-4-ol	16,460	0.19	0.15	0.11
β-Elemene	16,559	0.16	0.19	0.22
α-Guaiene	**16,743**	**4.07**	**4.58**	**5.86**
Caryophyllene	**17,151**	**4.67**	**7.94**	**8.71**
Myrtenal	17,648	-	0.12	0.13
Acetophenone	**17,967**	**41.56**	**33.26**	**23.16**
trans-Pinocarveol	18,217	0.09	-	0.13
α-Patchoulene	18,713	1.57	2.00	2.67
Seychellene	**18,897**	**2.69**	**3.67**	**4.84**
Humulene	19,508	1.21	1.76	2.32
endo-Borneol	19,772	0.24	-	-
β-Curcumene/α-Longipinene	19,858	0.26	1.38	2.19
Aciphyllene	20,527	0.64	0.64	1.11
γ-Muurolene	20,846	0.09	0.31	0.17
α-Bulnesene	**20,987**	**2.53**	**2.49**	**2.09**
β -Bisabolene	22,366	0.08	0.07	0.08
α-Curcumene	22,596	-	0.09	0.36
Myrtenol	22,829	0.17	0.20	0.37
2-Caren-4-ol	29,327	0.11	0.12	0.14
trans- Bisabolene epoxide	29,600	-	-	0.06
Caryophyllene oxide	29,821	0.22	0.44	0.77
trans-Nerolidol	**30,524**	**17.17**	**11.52**	**9.03**
Ledene oxide-(II)	32,368	-	0.17	0.34
α-Acetylacetophenone	33,001	1.39	0.64	0.11
1,3-Butanedione, 1-phenyl-	33,061	-	-	0.48
Globulol	33,154	0.52	0.49	0.72
Thymol	33,771	0.93	0.30	0.46
Isoaromadendrene epoxide	33,865	-	0.17	0.23
Patchouli alcohol	**34,139**	**17.30**	**24.60**	**28.30**
Pogostole	**34,373**	**0.78**	**1.08**	**1.24**
α-Cadinol	34,747	-	-	
E-2-Hexenyl benzoate	35,253	0.20	0.10	-
TOPLAM		100	100	98.56

Galovicová ve ark. (2022) *Pogostemon cablin*'in uçucu yağın analizinde %31.0 patçuli alkol, %21.3 α-bulnesen, %14 α –guaien ve %6.9 seyşellen olduğunu göstermektedir. Bure ve Sellier (2004) araştırmalarında uçucu yağda %32.2 patçuli alkol, %5.3 seyşellen, %3.3 β- karyofilen, %5.5 α,- patçulen olarak bulmuşlardır. Paçuli üzerine yapılan çeşitli araştırmalarda patçuli alkol oranını %26.27 - 36.63 arasında değiştiğini saptamışlardır (Doneliana ve ark., 2009; Swamy ve Sinniah, 2016; Pandey ve ark. 2020; Galovicová ve ark. 2022). Bununla beraber bazı araştırıcılar ise patçuli alkol oranının % 37.54–64.9 arasında değiştiğini belirtmektedirler (Singh ve ark., 2002; Chen ve ark. 2014; Shah ve ark., 2017). Literatürler incelendiğinde elde edilen bulgular bazı araştırıcıların verileri ile kısmi benzerlik gösterirken bazılarının değerlerinden düşük çıkmıştır. Jain ve ark. (2022) bildirdiği üzere bu

farklılıklar, iklim koşullarına ve hasat zamanlarına göre değişkenlik göstermektedir (Giray ve ark., 2008; Kaya ve ark., 2012; Maral ve ark., 2018; Maral & Kırıcı, 2019; Çalışkan ve ark. 2019). Patçuli alkol terapötik özellikler sayesinde tedavide kullanılmaktadır, güçlü in vitro antiviral, antifungal ve antimikrobiyal aktivitenin yanısıra antidepresan özelliklere sahiptir (Kiyohara ve ark., 2012; Cahyono ve ark., 2019; Pandey ve ark., 2022). Pogostol, 1990'larda Paçuli yağında izole edilmiş bir bileşendir (Van Beek ve Joulain, 2017). Verma ve ark (2012) araştırmalarında P. cablin'in uçucu yağında bulunan pogostone %1.0, ve pogostol % 0.5 paçulinin karakteristik bileşenleri olarak tanımlamışlardır. Pandey ve ark.(2020)'nin pogostol oranını en yüksek % 1.25 buldukları çalışmalarında elde edilen bulgularla kısmi benzerlik göstermektedir.

Paçuli bitkisinin uçucu yağının büyük bir kısmını oluşturan ana bileşenlerden asetofenon ve trans-nerolidolun çiçeklenme öncesinde yüksek oldukları, generatif dönem sonrasına doğru azaldıkları, patçuli alkol ve pogostolun çiçeklenme öncesinden çiçeklenme sonrasına doğru arttığı ortaya çıkmıştır (Şekil 1).



	Asetofenon(%)	Patçuli Alkol(%)	trans-Nerolidol(%)	Pogostol(%)
Çiçeklenme Öncesi	41.56	17.03	17.17	0.78
Tam Çiçeklenme	33.26	24.06	11.52	1.13
Çiçeklenme Sonrası	23.16	28.03	9.03	1.48

Şekil 1. *Pogostemon cablin* bitkisinin önemli uçucu yağ bileşenleri

Sonuç

Paçuli (*Pogostemon cablin*) bitkisinin uçucu yağı, dünya üzerinde ekonomik değerinin yüksek olduğu ve parfüm sanayisinde çokça kullanıldığı için önemli bir yere sahiptir. Paçuli bitkisinin Çukurova koşullarında uygun biçim zamanı ve verim özelliklerini belirlemek amacıyla yapılan bu çalışmada %0.96-1.77 oranında uçucu yağ elde edilmiştir. Uçucu yağların ana bileşenlerinin Asetofenon, Patçuli alkol, trans-Nerolidol; diğer bileşenlerin ise α-Bulnesen, α.-Guaien, Karyofilen, Pogostol, Seyşellen olduğu ve bu bileşenlerin oranlarının bitkinin biçim zamanına göre değişim gösterdiği saptanmıştır. Araştırma sonucunda gerek verim değerleri, gerek uçucu yağ oranı ve etkili madde bileşenleri bakımından yetiştirilebileceği ortaya çıkmıştır. Çukurova koşullarına en uygun biçim zamanının çiçeklenme sonrası dönem olduğunu ortaya konmuştur. Küresel pazarlarda yer almak için *P. cablin* uçucu yağunda patçuli alkol oranının %26-40 arasında olması gerekmektedir (Cornwell 2010). Bu bölgede elde edilen sonuçların standartlara uygun olduğunu belirlenmiştir. Bu araştırma bölgede yapılan ilk yetiştiricilik araştırması olup, verim ve kalite değerlerinin artırılması için daha fazla araştırma yapılmalıdır.

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The Impact of Socio-Demographic Characteristics of Consumers on Food Preferences: The Case of Türkiye

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Abstract

This study examines the relationship between consumers' socio-demographic characteristics and the key factors influencing food purchasing decisions in Turkey. The research is based on the Food Choice Questionnaire (FCQ), which identifies nine major factors affecting food preferences: health, mood, convenience, sensory appeal, natural content, price, weight control, familiarity, and ethical concerns regarding the origin and packaging of food. The study employs a face-to-face survey methodology, conducted in seven major cities across Turkey, with a total of 1,016 participants. Using an ordered probit model, the analysis reveals significant relationships between socio-demographic variables (gender, marital status, age, education, income, and household size) and food choice factors. Key findings indicate that women are more concerned with health, natural content, and ethical considerations than men, while older consumers and individuals with higher incomes prioritize health and organic food choices. Additionally, consumers with higher income levels are more likely to focus on weight control, whereas those with lower incomes tend to prioritize affordability and accessibility. The findings contribute to a deeper understanding of how socio-demographic characteristics shape food choices, providing insights for policymakers, food industry professionals, and public health initiatives. The results emphasize the importance of targeted marketing strategies and public health interventions to promote healthier and more sustainable dietary habits across different consumer groups.

Key Words: Food Choice, Socio-Demographic Factors, Consumer Behavior, Ordered Probit Model, Turkey

Tüketicilerin Sosyo-Demografik Özelliklerinin Gıda Tercihleri Üzerindeki Etkisi: Türkiye Örneği

Özet

Bu çalışma, tüketicilerin sosyo-demografik özellikleri ile gıda satın alma kararlarını etkileyen temel faktörler arasındaki ilişkiyi Türkiye örneğinde incelemektedir. Araştırma, gıda tercihlerini belirleyen dokuz ana faktörü (sağlık, ruh hali, hazırlama kolaylığı, duyusal çekicilik, doğal içerik, fiyat, kilo kontrolü, aşinalık ve gıdanın kökeni ile ambalajına yönelik etik kaygılar) temel alan Gıda Seçim Anketi (Food Choice Questionnaire - FCQ) çerçevesinde yürütülmüştür. Çalışma, Türkiye'nin yedi büyük kentinde gerçekleştirilen yüz yüze anketler aracılığıyla 1.016 tüketiciden elde edilen veriler üzerine kurulmuştur. Sıralı probit modeli kullanılarak yapılan analizler, sosyo-demografik değişkenler (cinsiyet, medeni durum, yaş, eğitim, gelir ve hanehalkı büyüklüğü) ile gıda seçim faktörleri arasında anlamlı ilişkiler olduğunu ortaya koymaktadır. Araştırma bulgularına göre, kadınlar sağlık, doğal içerik ve etik kaygılar konusunda erkeklere kıyasla daha duyarlıdır. Yaş ilerledikçe ve gelir seviyesi arttıkça sağlıklı ve organik gıdalara yönelik tercihler artmaktadır. Ayrıca, gelir seviyesi yükseldikçe kilo kontrolüne verilen önem artarken, düşük gelirli bireylerin daha çok ekonomik ve erişilebilir gıdaları tercih ettiği belirlenmiştir. Araştırma sonuçları, tüketicilerin gıda tercihlerini şekillendiren sosyo-demografik özelliklerin belirlenmesinin, kamu sağlığı politikaları, pazarlama stratejileri ve sürdürülebilir beslenme uygulamaları açısından kritik bir öneme sahip olduğunu göstermektedir. Bu doğrultuda, farklı tüketici gruplarına yönelik sağlık politikalarının geliştirilmesi ve pazarlama stratejilerinin çeşitlendirilmesi önerilmektedir.

Anahtar Kelimeler: Gıda Tercihi, Sosyo-Demografik Faktörler, Tüketici Davranışları, Sıralı Probit Modeli, Türkiye

Giriş

Tüketiciler günde yaklaşık 200 gıdayla ilgili seçim yaparak hem kendi beslenme alışkanlıklarını şekillendirir hem de gıda sisteminin işleyişi ve sürdürülebilirliği üzerinde doğrudan etkili olurlar (Scheibehenne ve ark, 2007; Asp, 1999). Gıda seçimi çok yönlü, durumsal, dinamik ve oldukça karmaşık bir süreçtir ve bir kişinin satın alma anında veya tüketim sırasında aldığı bilinçli ya da bilinçsiz bir dizi kararlar olarak tanımlanabilir. Tüketicinin tutumlarının bir arada etkileşen çeşitli faktörler tarafından yönlendirildiği ve bu faktörlerin her bireyin tüketim modelini belirleyen seçimlere yol açtığı bilinmektedir (Eertmans ve ark., 2005; Cabral ve ark., 2017; Kaya, 2016; Chen ve Antonelli, 2020).

Tüketicilerin gıda seçimlerini etkileyen unsurların tespiti, yalnızca etkili gıda ve sağlık politikalarının geliştirilmesi açısından değil, aynı zamanda yiyecek ve içecek sektöründeki işletmelerin pazarlama stratejilerini başarılı ve verimli bir şekilde uygulayabilmesi açısından da büyük önem taşımakta olup, bu durum tüketicilerin bir gıda ürününün piyasa başarısını belirlemedeki kritik rolünü de ortaya koymaktadır (Girgin ve Karakaş, 2017). Yapılan bir araştırma perakende sektörüne sunulan yeni gıda ürünlerinin %83'ünün başarısız olduğunu ortaya koymuştur. Bunun maliyeti ise 5–10 milyon Amerikan Doları düzeyindedir (Kaya, 2016; Asp, 1999). Bireysel yiyecek seçimlerini anlamak, mevcut gıda sistemini dönüştürmek ve sağlıklı bir toplum ile gezegenin sürdürülebilirliğini sağlamak açısından kritik bir öneme sahiptir.

Bireysel gıda seçimleri gıda tüketimlerinin desenlerinin değişmesine, çevre ve sağlık konularında tüketicilerin daha duyarlı hale gelmesine, biyolojik temellere, fiziksel ihtiyaçlara, yaşam tarzına ve teknolojinin gelişimine bağlı olarak zaman içinde büyük bir değişime konu olmuştur. Ayrıca, bireylerin yaşam ve çalışma şartlarındaki değişiklikler, COVİD-19 pandemisi gibi son yıllarda deneyimlediğimiz küresel halk sağlığı sorunları ve sağlıksız beslenmenin yol açtığı obezite, diyabet ve kalp hastalıkları gibi problemler, gıda tüketimi alışkanlıklarının hızla değişimine etkili diğer faktörlerdir. Bu gelişmeler, tüketicilerin beslenme tercihleri arasında benzerlikler ve farklılıklar oluşmasın neden olmuştur (Tsakiridou ve ark., 2009; Chen ve Antonelli, 2020; Öztürk ve Tekeli, 2021).

İnsanın gıda tercihi bir dizi karmaşık faktörden etkilenen bir süreçtir. Gıda ürünlerinin değerlendirilmesi ve satın alma kararları, tat, koku, besin içeriği veya dokusu gibi Gıdaya ilişkin unsurların yanı sıra fiziksel ortamı hem de bireysel tercihler, tutumlar, motivasyonlar gibi gıda dışı unsurların etkisi altında şekillenebilir (Eertmans ve ark., 2005; Scheibehenne ve ark, 2007). Gıda dışı etkenler ise bireylerin kişisel özelliklerine bağlı olarak değişir. Bu kişisel faktörler, bireylerin hoşlanmadıkları şeyler, tercihleri, demografik özellikleri, gıda odaklı psikolojik ve fizyolojik ihtiyaçları gibi özelliklerini kapsar (Girgin ve Karakaş, 2017).

Farklı araştırma alanlarında (örneğin, beslenme, psikoloji, sosyal bilimler, pazarlama vb.) yapılan çalışmalar, gıda seçimlerini etkileyen faktörler konusunda farklı bakış açılarıyla kanıt sunsa da, bu faktörleri üç temel kategori altında sınıflandırabiliriz. İlk olarak, gıda ile ilgili özellikler kapsamında içsel (örneğin, renk ve aroma) ve dışsal (örneğin, bilgi ve ambalaj) unsurlar öne çıkmaktadır. İkinci olarak, bireysel farklar biyolojik (örneğin, açlık, iştah ve tat), fiziksel (örneğin, erişim, yemek pişirme becerileri ve zaman), psikolojik (örneğin, ruh hali ve stres), bilişsel (örneğin, tutumlar, tercihler, inançlar ve bilgi) ve sosyal (örneğin, aile ve arkadaşlar) faktörler çerçevesinde değerlendirilmektedir. Son olarak, toplumla ilgili özellikler arasında kültür, ekonomik değişkenler (örneğin, fiyat ve gelir) ve politika gibi unsurlar yer almaktadır (Chen ve Antonelli, 2020).

Bireylerin yiyeceklere yönelik tutumlarını ölçmek için kullanılan araçlardan en yaygın olanı Steptoe ve ark., 1995 tarafından geliştirilen ve yiyecek seçimiyle ilgili çok boyutlu motivasyon ölçümünün geliştirilmesini sağlayan Gıda Seçim Anketi (Food Choice Questionnaire-FCQ)'dir. Yiyecek Seçimi Anketi (FCQ), 18 ila 87 yaş aralığındaki 358 yetişkinden oluşan bir örneklemden alınan yanıtların ile geliştirilmiştir. Buna göre tüketicilerin gıda tercihlerini belirleyen dokuz faktör ortaya çıkmıştır. Bu faktörler sağlık, ruh hali, hazırlama kolaylığı, duyusal çekicilik (tat, koku), doğal içerik, fiyat, kilo kontrolü, aşinalık ve yiyeceğin kökeni ve ambalajı ile ilgili etik kaygılardır. Gıda Tercihi Anketi (FCQ), gıda tercihi araştırma alanında en yaygın kullanılan ve uyarlanan yöntem olmuştur (Phan ve Chambers, 2016) Baskın gıda seçimi motivasyonları olarak da tanımlayabileceğimiz bu faktörler ülkeler ve hatta ülke içerişindeki topluluklar arasında farklı etkiler yaratabilmektedir (Gama ve ark., 2018).

Ampirik kanıtlar, sosyo-demografik faktörlerin dünya genelinde gıda tüketim desenlerini belirlemede önemli bir rol oynadığını savunmaktadır. Bu nedenle yaş, istihdam durumu, etnik köken, cinsiyet ve eğitim seviyesi davranışsal çalışmalarda tüketicilerin tutumlarını ve beslenme bilgilerini anlama düzeylerini analiz etmek için yaygın olarak kullanılan faktörlerdir. (Konttinen ve ark., 2021; Krige ve ark., 2012; Ali ve ark., 2021; Ali ve ark., 2010; Ogundijo ve ark., 2022).

Bireylerin gıda tüketim tercihleri, gelir, eğitim, yaş, cinsiyet ve yaşanılan coğrafi bölge gibi sosyo-demografik faktörlerden etkilenmektedir. Gelir seviyesi yükseldikçe organik ve sağlıklı gıdalara yönelim artarken, düşük gelir grubundaki bireyler daha çok ekonomik ve erişilebilir gıdaları tercih etmektedir (Güney ve Sangün, 2019). Eğitim düzeyi yükseldikçe sağlıklı beslenme bilinci artmakta, bu da tüketicilerin besin değeri yüksek ve sürdürülebilir gıdalara yönelmesine neden olmaktadır (Kırcı Çevik ve Kıran, 2022). Yaş ve cinsiyet de gıda tercihlerini şekillendiren önemli değişkenlerdir. Genç tüketiciler daha fazla hızlı ve işlenmiş gıdalara yönelirken, yaş ilerledikçe geleneksel ve sağlıklı besinlere eğilim artmaktadır (Duru ve Seçer, 2019). Kadınlar genellikle daha sağlıklı ve dengeli beslenme eğilimindeyken, erkekler protein ağırlıklı gıdalara yönelmektedir (Cömert ve Durmaz, 2006).

Gıda tercihi, üretim sistemleri üzerinde doğrudan etkisi olan karmaşık bir süreçtir. Bu yüzden, tüketicilerin gıda seçimlerini belirleyen faktörlerin tespit edilmesi, hem yeni ürünlerin geliştirilmesi hem de pazarlama stratejilerinin etkili bir şekilde yönetilmesi açısından kritik bir rol oynamaktadır (Girgin ve Karakaş, 2017). Bu araştırmada Yiyecek Seçimi Anketine (FCQ) göre belirlenmiş olan tüketicilerin gıda tercihlerini belirleyen dokuz faktörün sosyo-demografik özelliklerdeki farklılıklardan nasıl etkilendikleri analiz edilmiştir. Bu bağlamda, araştırma sonuçları insanların gıda tercihlerini nasıl şekillendirdiğini anlamak, sağlıklı beslenme alışkanlıklarının teşvik edilmesinden, dağıtım ve pazarlama süreçlerindeki zorlukların giderilmesine kadar, küresel gıda sektöründe yaşanan sosyal ve ekonomik problemlerin çözümüne önemli katkılar sağlamaktadır.

Materyal ve Yöntem

Materyal

Araştırma kapsamında, tüketicilerin sosyo-demografik özelliklerinin gıda satın alım tercihlerini nasıl etkilediğini belirlemek amacıyla yüz yüze anket uygulaması yapılmıştır. Anket, Türkiye'nin yedi bölgesinin (İstanbul, Ankara, İzmir, Trabzon, Adana, Van ve Gaziantep) en büyük şehirlerinde Nisan-Temmuz 2023 tarihleri arasında gerçekleştirilmiştir. Her bir şehir için örneklem büyüklüğü toplam ülke nüfus içindeki oranına göre belirlenmiştir. Anket, ticari bir araştırma şirketi (Ayna Araşturma) tarafından 1.016 tüketiciye uygulanmıştır. Örneklem büyüklüğü, sonsuz bir popülasyon ve %95 güven düzeyi (p = 0,05) kullanılarak belirlenmiştir.

Ankete katılan bireylerin sosyo-demografik özellikleri Tablo 1 de gösterilmektedir. Sosyo-demografik özellikler aynı zamanda araştırmada bağımlı değişkenler olarak kullanılarak tüketicilerin gıda tercih davranışlarını açıklamada kullanılacaktır.

Tablo 1. Örnekleme katılan tüketiclerin sosyo-demografik özellikleri

	f	%		*f*	%
Cinsiyet			*Gelir (₺)*		
Erkek	457	45	Sabit gelir yok	258	25,4
Kadın	559	55	<5500	177	17,4
Yaş			5501–7500	248	24,4
15–24	247	24,3	7501–9000	153	15,1
25–34	334	32,9	9001–11500	95	9,4
35–44	213	21	>11501	85	8,4
45–54	139	13,7	*Eğitim*		
55–65	68	6,7	Okuma yazma yok	15	1,5
≥65	15	1,5	İlk-ortaokul	232	22,8
Hane kişi sayısı			Lise	263	25,9
1	87	8,6	Univerite	449	44,2
2	141	13,9	Lisan üstü	57	5,6
3	271	26,7	*Medeni durum*		
4 ve üzeri	252	24,8	Bekâr	501	49,3
			Evli	515	50.7

Gıda Seçim Anketi Faktörleri	Açıklama
Sağlık	Sağlığa faydalı ve besleyici yiyecekleri tercih etmek.
Ruh Hali	Kendini iyi hissettiren, stresi azaltan yiyecekleri seçmek.
Hazırlama Kolaylığı	Hızlı ve pratik şekilde hazırlanabilen yiyecekleri tercih etmek.
Duyusal Çekicilik	Lezzet, koku ve görünüş gibi duyusal faktörlere dayalı yiyecek seçimi.
Doğal İçerik	Doğal, katkı maddesi içermeyen, en az işlenmiş gıdaları tercih etmek.
Fiyat	Yiyecek satın alırken fiyatı göz önünde bulundurmak.
Kilo Kontrolü	Kilo almaktan kaçınmak için düşük kalorili gıdaları tercih etmek.
Aşinalık	Daha önce tüketilmiş ve bilinen yiyecekleri seçmek.
Yiyeceğin Kökeni ve Ambalajı	Çevresel ve etik kaygılarla sürdürülebilir üretim yapılan yiyecekleri tercih etmek.

Anket kapsamında Gıda Seçimi Anketine tespit edilmiş olan 9. faktör (sağlık, ruh hali, hazırlama kolaylığı, duyusal çekicilik, doğal içerik, fiyat, kilo kontrolü, aşinalık ve yiyeceğin kökeni ve ambalajı) sırasıyla bağımlı değişkenler olarak kabul edilmiştir. Diğer taraftan sosyo-demografik değişkenler ise (cinsiyet, medeni, durum, yaş, eğitim, gelir, hane kişi sayısı) ise analizin bağımsız değişkenleridir. Tüm sorular, yanıtları sıralı bir şekilde ölçmek için bir Likert ölçeği kullanılarak tasarlanmıştır.

Yöntem

Tüketicilerin gıda tercihlerini belirleyen 9 temel faktör ile sosyo-demografik özellikler arasındaki ilişki sıralı bir probit modeli kullanılarak belirlenmiştir. Sıralı Probit modeli, doğal bir sıralamaya sahip olan kategorik bağımlı değişkenlerin modellenmesi için kullanılan bir regresyon modelidir. Bu model, özellikle ekonometrik ve sosyal bilimler alanlarında yaygın olarak kullanılmaktadır (Greene, 2018). Modelin seçimi, anket sorularının (hem bağımlı hem de bağımsız değişkenler) bir Likert ölçeği kullanılarak düşükten yükseğe doğru sıralanmasına dayanmaktadır. Lojistik dağılımdan türetilen olasılık oranları yerine probit analizi olay olasılıklarını kümülatif standart normal dağılım puanlarına dönüştürmektedir (Harrell, 2015).

Sıralı probit modeli aşağıdaki gibi tanımlanabilir;

$$y_i^* = x_i'\beta + \varepsilon_i \quad (1)$$

Burada , tüketicileri ifade etmektedir , bağımsız açıklayıcı değişkenler vektörüdür, ilinmeyen eğim parametreleri vektörünü temsil eder ve standart lojistik dağılıma sahip gözlemlenemeyen bireysel hata terimidir. Kısaca, sıralı probit modelinde, bağımlı değişken (yani bireylerin tüketim sıklığı), gözlemlenemeyen gizli değişken tarafından belirli eşik aralıkları içinde aldığı değerlere göre sınıflandırılır.

= 0 eğer $y* \leq 0$ (2)
= 1 eğer $0 < y* \leq \mu1$
= 2 eğer $\mu1 < y* \leq \mu2$
.
.
.
= J eğer $\mu J-1 \leq y*$,

Burada μ değeri ile birlikte tahmin edilmesi gereken bilinmeyen parametrelerdir (Greene, 2012).

Ampirik analiz için, veri analizi kapsamında tanımlayıcı istatistikler SPSS 21 programı kullanılarak hesaplanmış, sıralı probit regresyon modeli ise STATA programı ile analiz edilmiştir.

Bulgular ve Tartışma

Araştırmada tüketicilerin sosyo-demografik özelliklerinin Gıda Seçim Anketince belirlenmiş olan 9 faktör ile ilişkileri analiz edilmiştir. Sıralı Probit Modeli kullanılarak yapılan analizler sonucunda sosyo-demografik özellikler ile gıda satın almayı etkiyen kilo kontrolü, hazırlama kolaylığı, aşinalık, sağlık, etik kaygılar ve doğal içerik faktörleri arasında anlamlı ilişkiler tespit edilmiştir. Bu ilişkilerin anlamlılık düzeyleri ve yönleri tablolar (Tablo 1…Tablo 5) yardımıyla gösterilmektedir.

Tablo 1. Sağlık faktörü ile sosyo-demografik özellikler arasında ilişkiler

	Katsayı	Std. Hata	P > |z|	[95% Güven Aralığı]	
Değişkenler					
Cinsiyet	-.31057	.07415	0.000***	-.45591	-.16524
Medeni durum	.06044	.09062	0.505	-.11717	.23807
Yaş	.09824	.03685	0.008***	.02601	.17047
Eğitim	.05485	.04244	0.196	-.02834	.13805
Gelir	.10840	.02515	0.000***	.05910	.15770
Hane kişi sayısı	.04365	.02921	0.135	-.01360	.10090

* $p < 0.01$, ** $p < 0.05$, *** $p < 0.010\%$; LR $\chi2$ (27) = 208.37; Prob > $\chi2$ = 0.0000

Tablo 1, gıda seçimini etkileyen faktörlerden sağlık faktörü ile sosyo-demografik özellikler arasındaki ilişkiyi göstermektedir. Bulgular cinsiyet, yaş ve gelir değişkenleri ile sağlık faktörü arasında istatistiksel olarak anlamlı ilişkiler olduğunu ortaya koymaktadır. Özellikle kadınlar, yüksek gelir grubundakiler ve yaşça büyük bireylerin sağlıklı beslenmeye daha fazla önem verdikleri gözlemlenmiştir.

Benzer sonuçlara başka akademik çalışmalarda da ulaşılmıştır. Steptoe ve ark., (1995) tarafından yürütülen çalışmada, kadınların sağlık faktörüne erkeklerden daha fazla önem verdikleri belirlenmiştir. Araştırma kadınların tuz ve yağ tüketimini kısıtlama eğilimlerinin daha yüksek olduğunu ve lif alımına daha fazla özen gösterdiklerini ortaya koymaktadır. Benzer şekilde Girgin'in (2017) de çalışması da kadınların gıda tercihlerinde sağlık faktörünü

erkeklerden daha çok göz önünde bulundurduklarını göstermektedir. Beardsworth ve ark., (2002) cinsiyet farklılıklarını ele aldıkları çalışmalarında elde edilen bulgular kadınların sağlık endişelerini dikkate alarak gıda tüketimlerini aktif olarak düzenlemeye daha yatkın olduklarını ortaya koymaktadır.

Bununla birlikte, tüketicilerin yaşı arttıkça sağlık faktörüne verdikleri önem de artmaktadır. Bireylerin yaşlanması, sağlık konusunda daha bilinçli ve dikkatli olmalarına yol açmakta, bu da beslenme alışkanlıklarını daha sağlıklı gıdalara yönlendirebilmektedir. Konttinen ve ark., (2021) tarafından gerçekleştirilen araştırmada, yaşlı bireylerin (65–94 yaş), en genç yaş grubundaki bireylere (18–29 yaş) kıyasla gıdaların sağlık yönüne daha fazla önem verdikleri tespit edilmiştir. Ricciuto ve ark., (2006) göre de yaşlı bireylerde sağlık endişeleri gençlere kıyasla gıda seçimlerini daha fazla etkilemektedir.

Son olarak elde edilen sonuçlardan (Tablo1) gelir seviyesinin artmasıyla sağlıklı gıda tercih etme eğiliminin de yükseldiği gözlemlenmektedir. Buna göre yüksek gelir gruplarındaki bireyler sağlık faktörüne diğer gelir gruplarına göre daha fazla önem vermekte ve daha sağlıklı gıdalara yönelmektedirler. Ricciuto ve ark., (2006)'nun çalışmaları düşük gelir seviyesinin genel olarak sağlık açısından önerilen gıdaların (örneğin sebze, meyve ve süt ürünleri) satın alınmasını kısıtlayan önemli bir faktör olduğunu ve bu durumun özellikle dezavantajlı gruplara yönelik hedeflenmiş müdahalelerin gerekliliğini ortaya koyduğunu göstermektedir. Benzer şekilde, Drewnowski ve Specter (2004) da sağlıksız beslenme alışkanlıklarının en çok yoksulluk oranı yüksek ve eğitim seviyesi düşük nüfus gruplarında görüldüğünü belirtmiştir. Darmon ve Drewnowski (2008) tarafından gerçekleştirilen araştırma ise düşük gelirli bireylerin genellikle daha düşük diyet kalitesine sahip olduklarını ve bunun sağlık üzerinde olumsuz etkileri olduğunu göstermektedir. Ayrıca, Giskes ve ark., (2010) da düşük sosyo-ekonomik statüye sahip bireylerin daha sağlıksız diyet alışkanlıklarına sahip olma eğiliminde olduklarını tespit etmişlerdir.

Tablo 2. Kolaylık faktörü ile sosyo-demografik özellikler arasında ilişkiler

	Katsayı	Std. Hata	P > |z|	[95% Güven Aralığı]	
Değişkenler					
Cinsiyet	-.219302	.06976	0.002***	-.35603	-.08256
Medeni durum	-.184129	.08450	0.029**	-.34975	-.01850
Yaş	.04549	.03386	0.179	-.02088	.11188
Eğitim	.04169	.03986	0.296	-.03643	.119820
Gelir	.06935	.02367	0.003***	.02294	.11575
Hane kişi sayısı	.01545	.02761	0.576	-.03867	.06957

* $p < 0.01$, ** $p < 0.05$, *** $p < 0.010\%$; LR $\chi2$ (27) = 208.37; Prob > $\chi2$ = 0.0000

Gıda tercih anketi (FCQ) kapsamında bireylerin gıda seçimlerini etkileyen faktörlerden bir diğeri olan kolaylık faktörü ile cinsiyet, medeni durum ve gelir değişkenleri arasında anlamlı ilişkiler olduğu tespit edilmiştir (Tablo 2). Bulgular kadınların ve bekar bireylerin hızlı ve pratik şekilde hazırlanabilen gıdalara daha önem verdiklerini ve bu özelliklere sahip gıdalara yönelik talep olasılığının daha yüksek olduğunu göstermektedir. Girgin ve Kaya (2017) araştırması da kolaylık faktörünün kadınlar ve bekar bireyler tarafından önemli görüldüğünü ortaya koymaktadır. Benzer şekilde Marsola ve ark., (2020) Brezilya'da yiyecek seçimi motivasyonlarını değerlendirdikleri araştırmalarında aynı sonuca ulaşmış ve kadınların, erkeklere kıyasla kolaylığı daha önemli bir faktör olarak değerlendirdiğini belirlemişlerdir.

Öte yandan, gelir düzeyi arttıkça bireylerin yiyecek seçiminde kolaylık faktörüne verdikleri önemin arttığı gözlemlenmiştir. Buna karşın, bazı araştırmalar gelir düzeyi arttıkça bireylerin gıda tercihlerinde hazırlama kolaylığı faktörüne daha fazla önem verdiklerini öne sürmektedir Szakály ve ark., (2018) tarafından yürütülen "Gıda Seçimi Anketinin Uyarlanması: Macaristan Örneği" başlıklı araştırmada daha yüksek gelir seviyesine sahip bireylerin yiyecek seçimlerinde kolaylığa daha az önem verdikleri sonucuna ulaşılmıştır.

Tablo 3. Etik kaygı faktörü ile sosyo-demografik özellikler arasında ilişkiler

	Katsayı	Std. Hata	P > |z|	[95% Güven Aralığı]	
Değişkenler					
Cinsiyet	-.37970	.08813	0.000***	-.55244	-.20696
Medeni durum	.05829	.10728	0.587	-.15197	.26855
Yaş	.02743	.04336	0.527	-.05754	.11242
Eğitim	.06146	.04928	0.212	-.03513	.15805
Gelir	.15007	.03041	0.000	.09045	.20969
Hane kişi sayısı	.05065	.03412	0.138	-.01622	.11754

* $p < 0.01$, ** $p < 0.05$, *** $p < 0.010\%$; LR $\chi2$ (27) = 208.37; Prob > $\chi2$ = 0.0000

Tablo 3'te sunulan analiz sonuçlarına göre gıda tercihlerinde etik kaygılara önem veren bireylerin çoğunlukla kadınlar ve yüksek gelir grubuna mensup kişiler olduğu görülmektedir. Bu gruptaki bireyler çevresel sürdürülebilirlik, hayvan hakları ve etik üretim süreçlerine daha fazla duyarlılık göstermektedirler. Steptoe ve ark., (1995) tarafından yapılan bir araştırmada da etik kaygı derecelendirmesinin kadınlarda erkeklere kıyasla daha yüksek olduğu tespit edilmiştir. Beardsworth ve ark., (2002) yürüttüğü çalışmalar da gıda tercihinde ahlaki boyutların kadınlar tarafından erkeklere kıyasla daha fazla dikkate alındığı belirtilmiştir. Buna göre, kadınlar gıda seçimlerini hayvan refahı ve ekolojik faktörleri göz önünde bulundurarak yapma eğilimindedirler. Benzer şekilde, Pohjanheimo ve Sandell (2009) tarafından yoğurt tüketiminde tercih motivasyonları üzerine yapılan bir araştırmada da kadınların yogurt tercihlerinde etik kaygı faktörünü erkeklerden daha yüksek değerlendirdiği sonucuna ulaşılmıştır.

Tablo 4. Aşinalik fakörü ile sosyo-demografik özellikler arasında ilişkiler

	Katsayı	Std. Hata	P > |z|	[95% Güven Aralığı]	
Değişkenler					
Cinsiyet	-.11323	.07128	0.112	-.25294	.02648
Medeni durum	-.12454	.08691	0.152	-.29489	.04579
Yaş	.11424	.03513	0.001***	.04539	.18310
Eğitim	-.04668	.04089	0.254	-.12682	.03346
Gelir	.11946	.02438	0.000***	.07168	.16725
Hane kişi sayısı	.03003	.02835	0.290	-.02554	.08561

* $p < 0.01$, ** $p < 0.05$, *** $p < 0.010\%$; LR $\chi2$ (27) = 208.37; Prob > $\chi2$ = 0.0000

Aşinalık bireyin yiyecek seçimlerinde alıştığı beslenme düzenine bağlı kalma eğilimini ve yeni tatlar denemeye yönelik istekliliğini ifade etmektedir. Araştırma sonuçlarına göre gıda tercihlerinde etkili olan önemli faktörlerden biri olan aşinalık yaş ve gelir düzeyi ile anlamlı bir ilişki içerisindedir (Tablo 4). Araştırma bulgularına göre bireylerin yaşı arttıkça daha tanıdık ve bilindik gıda ürünlerine yönelme eğilimindedirler. Ayrıca aşinalık faktörü ile gelir düzeyi arasında da pozitif ve anlamlı bir ilişki bulunmaktadır. Tüketicilerin gelir düzeyi arttıkça, bilinen markalara yönelme olasılıkları da yükselmektedir.

Steptoe ve ark., (1995) tarafından yapılan bir çalışmada da yaşlı bireylerin gıda seçimlerinde daha az maceracı oldukları sonucuna ulaşılmıştır. Ancak aynı çalışmada düşük gelirli bireylerin aşinalık faktörüne daha fazla önem verdiği belirlenmiştir. Mevcut araştırmanın bulgularının aksine bazı çalışmalar tüketicilerin gelir düzeyi arttıkça yalnızca tanıdık yiyeceklere bağlı kalma eğilimlerinin azaldığını ve gıda seçimlerinde daha fazla risk alabildiklerini göstermektedir. Konttinen ve ark., (2021) yürüttüğü araştırmada en yüksek gelir grubundaki katılımcıların en düşük gelir grubuna kıyasla aşinalık faktörüne daha az önem verdiği belirlenmiştir. Marsola ve ark., (2020) tarafından yapılan bir diğer çalışmada ise gelir, yaş ve cinsiyet gibi faktörlerin aşinalık dahil olmak üzere yiyecek seçimi motivasyonlarını önemli ölçüde etkilediği ortaya konmuştur. Bu araştırmanın sonuçlarına göre de yüksek gelir düzeyi aşinalık faktörüyle negatif bir ilişki göstermekte ve daha düşük aşinalık puanları ile ilişkilendirilmektedir.

Tablo 5. Doğal içerik faktörü ile sosyo-demografik özellikler arasında ilişkiler

	Katsayı	Std. Hata	P > |z|	[95% Güven Aralığı]	
Değişkenler					
Cinsiyet	-.157519	.0762785	0.039**	-.307022	-.008015
Medeni durum	.1340564	.1340564	0.149	-.048154	.316267
Yaş	.316267	.316267	0.001***	.051506	.201666
Eğitim	-.003788	.044322	0.932	-.090657	.083081
Gelir	.1048216	.0261618	0.000***	.0535455	.156097
Hane kişi sayısı	.100988	.030105	0.001***	.041983	.159994

* $p < 0.01$, ** $p < 0.05$, *** $p < 0.010\%$; LR $\chi2$ (27) = 208.37; Prob > $\chi2$ = 0.0000

Tablo 5'te sunulan analiz sonuçlarına göre doğal, katkı maddesi içermeyen ve organik gıdaların tercih edilmesi ile cinsiyet, yaş, gelir düzeyi ve hanehalkı kişi sayısı arasında anlamlı ilişkiler bulunmaktadır. Tablo 5 deki sonuçlar kadınların organik ve doğal içerikli gıdalara erkeklere kıyasla daha fazla önem verdiğini göstermektedir. Ayrıca, yaş ve gelir düzeyinin artmasıyla birlikte bireylerin doğal içerikli gıdalara yönelik tercihlerinin de arttığı belirlenmiştir. Bunun yanı sıra, kalabalık ailelerin doğal içerikli gıda tüketme eğilimlerinin daha yüksek olduğu da analiz sonucunda ortaya çıkmıştır.

Girgin ve Kaya (2017) tarafından yürütülen bir çalışmada da benzer bulgular elde edilmiş olup, kadınların gıda tercihleri açısından doğal içerik faktörüne erkeklere oranla daha fazla önem verdikleri belirlenmiştir. Aynı

çalışmada tüketicilerin yaşı düzeyi arttıkça doğal içerikli gıdalara daha fazla önem verdikleri tespit edilmiştir. Konttinen ve ark., (2021) tarafından yapılan araştırma ise genç katılımcıların doğal içerik motivasyonuna daha az önem verdiğini ortaya koymuştur. Ayrıca, burada da kadınların doğal içerik faktörüne verdiği önemin erkeklere kıyasla istatistiksel olarak anlamlı düzeyde daha yüksek olduğu belirlenmiştir. Vorage ve ark., (2020) tarafından yapılan araştırmada da benzer şekilde kadınların besinlerin doğal içeriğine erkeklerden daha fazla önem verdikleri sonucuna ulaşılmıştır. Bu bulgular, bireylerin gıda seçimlerinde doğal içerik faktörüne verdikleri önemin demografik özellikler doğrultusunda oldukça farklılaştığını göstermektedir.

Tablo 6. Kilo kontrolü faktörü ile sosyo-demografik özellikler arasında ilişkiler

	Katsayı	Std. Hata	P > |z|	[95% Güven Aralığı]	
Değişkenler					
Cinsiyet	-.311485	.0845711	0.000***	-.477242	-.145729
Medeni durum	-.045851	.103098	0.657	-.247920	.1562179
Yaş	.0532415	.0418455	0.203	-.0287742	.1352572
Eğitim	.0807682	.0477512	0.091*	-.0128225	.1743589
Gelir	.109847	.0287622	0.000***	.053473	.1662204
Hane kişi sayısı	.032534	.033263	0.328	-.032660	.097729

* $p < 0.01$, ** $p < 0.05$, *** $p < 0.010\%$; LR $\chi 2$ (27) = 208.37; Prob > $\chi 2$ = 0.0000

Araştırma sonuçları kilo almaktan kaçınmak amacıyla düşük kalorili gıdaların tercih edilmesi ile cinsiyet, eğitim ve gelir düzeyi arasında anlamlı ilişkiler bulunduğunu göstermektedir (Tablo 6). Bulgular kadınların kilo kontrolüne erkeklere kıyasla daha fazla önem verdiğini ve gelir seviyesinin artmasıyla birlikte kilo kontrolüne verilen önemin de yükseldiğini ortaya koymaktadır. Ayrıca kilo kontrolüne önem verilmesiyle eğitim seviyesi arasında da pozitif anlamlı bir ilişki söz konusudur.

Steptoe ve ark., (1995) tarafından gerçekleştirilen çalışmada benzer sonuçlara ulaşılmış olup, Gıda Seçim Anketi'nin (FCQ) kilo kontrolü ölçeğindeki puanların kadınlarda erkeklere göre daha yüksek olduğu belirlenmiştir. Girgin ve Kaya (2017) tarafından yapılan araştırmada da kilo kontrolünün kadınlar açısından erkeklere kıyasla daha önemli bir faktör olduğu tespit edilmiştir. Beardsworth ve ark., (2002) ise kadınların kilo kaybını hedefleyen diyet değişiklikleri yapmaya erkeklere göre daha yatkın olduğunu belirtmektedir.

Szakály ve ark., (2018) Macaristan'da gerçekleştirdiği FCQ uyarlama çalışması da bu bulguları desteklemekte olup kadınların yiyecek seçimlerinde kilo kontrolü faktörünü erkeklere kıyasla daha fazla dikkate aldığını ortaya koymuştur. Ayrıca, Koç ve Yazıcıoğlu (2024) tarafından yapılan araştırmada, kadınların kilo kontrolünü sağlamak amacıyla sebze ve meyve gibi düşük kalorili besinleri erkeklere oranla daha fazla tercih ettiği tespit edilmiştir.

Köseoğullari ve Tunca (2024) araştırmalarında bireylerin eğitim seviyelerinin yükselmesiyle Vücut Kitle İndeksi (VKİ) değerlerinin ortalama olarak düştüğü bulgusuna erişmişlerdir. Bu durum eğitim seviyesinin yükselmesinin kilo kontrolü üzerinde olumlu bir etkiye sahip sonucununu ortaya koymaktadır. Benzer biçimde Earnest ve Church (2020) daha düşük eğitim düzeyine sahip bireylerin obezite prevalansının daha yüksek olduğu yani eğitim seviyesi arttıkça obezite riskinin azaldığı sonucuna ulaşmışlardır. Ayrıca Çın ve ark (2022) de obezite hastalarında sağlık okuryazarlığı ile sağlıklı beslenme tutumu ilişkisinin değerlendirilmesi isimli araştırmalarında eğitim seviyesi arttıkça sağlık okur yazarlığının ve dolayısıyla kilo kontrolüne yönelik olumlu tutumların arttığını belirtilmiştir.

Gelir seviyesi ile kilo kontrolü arasında pozitif ve anlamlı bir ilişki olduğunu gösteren bilimsel çalışmalar da mevcuttur. Örneğin Tedik, (2017) tarafından yapılan bir çalışmada, refah seviyesinin artması, beslenme şeklinin değişmesi, hazır gıda tüketiminin artması ve fiziksel aktivitenin azalması gibi faktörlerin obezite oranlarını artırdığı belirtilmiştir. Bentley ve ark (2018) araştırmalarına göre ABD'de 1990 yılında gelir ve obezite arasında bir ilişki bulunmazken, 2015 yılına gelindiğinde gelir ve obezite oranları arasında güçlü bir ters korelasyon geliştiğini göstermektedir ve gelir seviyesi arttıkça obezite olasılığı azalmaktadır. Selck, (2017) ise birçok çalışmanın gelir ve obezite arasında negatif bir ilişki bildirdiğini ve daha zengin bir kişinin obez olma olasılığının daha düşük olduğunu belirtmiştir.

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The Community Supported Agriculture Model: An Approach Based on Local Food Production and Solidarity

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Abstract

Community Supported Agriculture (CSA) has emerged as an innovative and sustainable alternative to industrialized food systems, addressing economic, social, and environmental challenges. This paper explores the core principles, benefits, and challenges of CSA while analyzing successful implementations worldwide, including Turkey. The findings highlight TDT's role in supporting small farmers, promoting local and seasonal production, strengthening community solidarity, and enhancing food sustainability. Case studies from countries such as Switzerland, France, the United States, Japan, and Turkey demonstrate how CSA models can adapt to diverse socio-economic conditions. Additionally, the study examines barriers to CSA expansion, including economic accessibility, legal recognition, and competition from industrial food systems. Despite these challenges, CSA remains a resilient model for sustainable agriculture, providing economic stability for farmers, fostering consumer engagement, and reducing the environmental impact of food production. To fully unlock CSA's potential, further policy support, financial incentives, and consumer awareness initiatives are needed. This study concludes that CSA offers a viable pathway toward localized, community-driven, and ecologically responsible food networks, contributing to global efforts for sustainable food security.

Key words: Community Supported Agriculture (CSA), Local Food Systems, Sustainable Agriculture, Small-Scale Farming,

Topluluk Destekli Tarım Modeli: Yerel Gıda Üretimi ve Dayanışmaya Dayalı Bir Yaklaşım

Özet

Topluluk Destekli Tarım (TDT) modeli, sosyo-ekonomik ve çevresel sorunlara yanıt olarak endüstriyel gıda sistemlerine yenilikçi ve sürdürülebilir bir alternatif olarak ortaya çıkmıştır. Bu çalışma çeşitli ülkelerdeki başarılı uygulamaları inceleyerek TDT'nin temel ilkelerini, sağladığı yararları ve etkilerini ortaya koymaktadır. Bulgular TDT'nin küçük ölçekli çiftçileri destekleme, yerel ve mevsimsel üretimi teşvik etme, toplumsal dayanışmayı güçlendirme ve gıda sistemlerinde sürdürülebilirliği artırmadaki rolünü vurgulamaktadır. Ülke örnekleri ise TDT modellerinin farklı sosyo-ekonomik koşullara nasıl uyum sağlayabildiğini göstermektedir. Çalışma ayrıca ekonomik erişilebilirlik, yasal tanınırlık eksikliği ve endüstriyel gıda sistemlerinin yarattığı rekabet gibi etmenlerin TDT'nin yaygınlaşmasının önündeki başlıca engeller olduğunu da ortaya koymaktadır. Tüm bu zorluklara karşın, TDT; çiftçilere ekonomik istikrar sağlayan, tüketicilerin üretim süreçlerine katılımını teşvik eden ve gıda üretiminin çevresel etkilerini azaltan dayanıklı bir sürdürülebilir tarım modeli olarak varlığını sürdürmektedir. TDT'nin potansiyelinin tam olarak hayata geçirilebilmesi için daha fazla politika desteği, finansal teşvik mekanizmaları ve tüketici farkındalığını artırıcı girişimlere ihtiyaç duyulmaktadır.

Anahtar kelimeler: Topluluk Destekli Tarım (TDT), Yerel Gıda Sistemleri, Sürdürülebilir Tarım, Küçük Ölçekli Çiftçilik

Giriş

Gıda Sistemlerindeki Güncel Sorunlar: Endüstriyel Tarımın Çevresel ve Ekonomik Etkileri

Günümüzde küresel gıda sistemleri endüstriyel tarımın çevresel ve ekonomik etkileri nedeniyle benzeri görülmemiş zorluklarla karşı karşıyadır. Büyük ölçekli endüstriyel gıda üretimi toprak erozyonu, su kirliliği, biyolojik çeşitlilik kaybı ve sera gazı emisyonları dahil olmak üzere önemli çevresel bozulmalara yol açmıştır (Vermeulen ve ark., 2012). Kimyasal gübre ve pestisitlerin yaygın kullanımı ekosistemleri bozmuş, toprak ve su kirliliğine katkıda bulunmuştur (Benton ve ark., 2021). Küresel gıda üretimi, tüm sera gazı emisyonlarının %35'inden sorumludur ve iklim değişikliğini şiddetlendirerek uzun vadeli gıda güvenliğini tehdit etmektedir (Higuita ve ark., 2023).

Ekonomik açıdan bakıldığında endüstriyel gıda sistemleri tarımsal verimi ön planda tutar ve bu da küçük ölçekli çiftçilerin ve yerel ekonomilerin aleyhine sonuçlar doğurur. Tarım sektöründe birkaç çokuluslu şirket başta tohum olmak üzere tarımsal girdilerin üretimi, işlenmesi ve dağıtımını kontrol etmekte ve piyasanın tekelleşmesine neden

olmaktadır (McMichael, 2014). Bu durum çiftlik gelirlerinin azalmasına, küresel tedarik zincirlerine bağımlılığın artmasına ve piyasa dalgalanmalarına karşı kırılganlığa neden olmaktadır. Ek olarak, uzun mesafeli gıda dağıtımına olan bağımlılık, gıda sistemlerinin karbon ayak izini artırırken ekonomik şoklara ve tedarik zinciri kesintilerine karşı dayanıklılığı azaltmıştır. COVID-19 salgını küresel gıda tedarik zincirlerinde ciddi kesintiler yaşamasına, fiyat oynaklığına ve gıda güvensizliğine yol açmış bu da tarım ve gıda sektöründe kırılganlıkları daha da belirginleştirmiştir (Laborde, 2020; Aday ve Aday, 2020).

Endüstriyel tarımın sınırlamaları daha belirgin hale geldikçe, alternatif gıda sistemleri (AGS) sürdürülebilir çözümler olarak dikkat çekmektedir. Bu modellerden biri de ekonomik ve ekolojik sürdürülebilirliği teşvik ederken tüketicileri gıda üretimiyle yeniden buluşturmayı amaçlayan Topluluk Destekli Tarım'dır (TDT).

Topluluk Destekli Tarım (TDT) Kavramının Ortaya Çıkışı ve Gelişimi

Topluluk Destekli Tarım TDT), endüstriyel gıda sistemlerinin ortaya çıkardığı çevresel, ekonomik ve sosyal zorluklara bir yanıt olarak ortaya çıkmıştır. Batı ülkelerinde TDT'nin ilham kaynağı olarak sıklıkla 1960'larda Japonya'da ortaya çıkan Teikei hareketi gösterilmektedir. Bu hareket, tüketicilerin bir taraftan yerel çiftçileri doğrudan desteklemesini diğer taraftan da taze ve organik gıdalara erişimini sağlamaya yönelik olarak geliştirilmiş bir Alternatif Gıda Sistemi (AGA)'dır (Kondo ve ark., 2024). Model, 1980'lerde Avrupa ve Kuzey Amerika'ya yayılmış ve burada yerel gıda egemenliğini, sürdürülebilir çiftçilik uygulamalarını ve doğrudan çiftçi-tüketici ilişkilerini vurgulayan çeşitli yapılara dönüşmüştür (Cone ve Myhre, 2000).

TDT o zamandan beri farklı kültürel ve ekonomik bağlamlara uyum sağlayarak dünya çapında genişlemiştir. Bazı TDT modelleri üyelerin mevsimlik hasatlar için önceden ödeme yaptığı abonelik temelinde çalışırken, diğerleri yetersiz hizmet alan nüfuslar için gıda erişimini artırmayı amaçlayan kooperatif çiftçilik uygulamalarını veya sosyal girişimleri entegre etmektedir (Middendorf ve Rommel, 2024). Bölgesel farklılıklara rağmen, TDT'nın temel ilkesi aynı kalmaktadır, ekolojik tarım ve yerel gıda sistemlerinde dayanıklılığı garanti altına almak için karşılıklı olarak faydalı bir ortaklık yaratmak.

TDT Konularının Tanımı ve Önemi

TDT, tüketicilerin hasattan bir pay karşılığında çiftliklere doğrudan finansal destek sağladığı, üreticiler ve tüketiciler arasındaki bir ortaklık olarak tanımlanmaktadır. Bu model, gıda egemenliğine, çevresel yöneticiliğe ve sosyal eşitliğe öncelik vererek geleneksel tedarik zincirleriyle çelişmektedir (González-Azcárate ve ark., 2023). TDT, daha kısa tedarik zincirlerini teşvik eder, gıda tedarik zincirinin boyunu kısaltır ve küçük çiftliklerinin ekonomik uygulanabilirliğini artırarak gıda sistemlerinin yerelleştirilmesine ve demokratikleştirilmesine katkıda bulunur (Degens ve Lapschieß, 2023).

TDT'nın önemi gıda üretiminin ötesine uzanarak toplumsal değişim için bir araç görevi görür, topluluk bağlarını güçlendirir, tüketici farkındalığını artırır ve tarımsal ekolojik uygulamaları teşvik eder (Fomina ve ark., 2022). Ancak, ekonomik sürdürülebilirlik, erişilebilirlik ve ölçeklenebilirlik açısından zorluklar da söz konusudur. Birçok TDT girişimi stabil olmayan üyelik, mevsimsel üretime bağımlılık ve sınırlı destekler nedeniyle finansal istikrarla mücadele etmektedir (Medici ve ark., 2021). Ayrıca, TDT üyeliği genellikle daha yüksek gelirli nüfuslara doğru kaydığı ve kapsayıcılığını sınırladığı için sosyal adalet sorunları da ortaya çıkmkatadır (Misra, 2023). Bu zorlukların ele alınması, TDT'nın endüstriyel tarıma ölçeklenebilir bir alternatif haline gelmesi ve sürdürülebilir, yerel gıda sistemlerinin herkes için erişilebilir olmasını sağlaması için çok önemlidir.

TDT gelişmeye devam ederken, çevresel, ekonomik ve sosyal boyutlarını anlamak, sürdürülebilir ve dayanıklı gıda sistemlerini destekleyen politikaları ve uygulamaları ilerletmek için elzemdir. Bu makale, mevcut sınırlamalarını ve gelecekteki beklentilerini ele alırken TDT'nın gıda üretimi ve dağıtımı için dönüştürücü bir model olarak potansiyelini keşfetmeyi amaçlamaktadır.

TDT Modelinin Temel İlkeleri

TDT, sürdürülebilir ve yerelleştirilmiş gıda sistemleri oluşturmayı amaçlayan dönüştürücü bir gıda üretim ve dağıtım modelini temsil eder. Bu model özünde üreticiler için ekonomik güvenliği teşvik ederken tüketicilerin de taze, doğal, mevsimlik ve yerel olarak üretilen gıdalara erişimini sağlayan çiftçiler ve tüketiciler arasındaki doğrudan bir ortaklığa dayanır. TDT modeli üretici-tüketici ortaklıkları, küçük ölçekli çiftçiliğin ve toplum dayanışmasının güçlendirilmesi, yerel ve mevsimlik üretimin teşvik edilmesi ve ekonomik, sosyal ve çevresel sürdürülebilirliğe bağlılık gibi çeşitli temel ilkeler üzerine kurulmuştur.

Üretici-Tüketici Ortaklığı

TDT'nin tanımlayıcı özelliği, üreticilerle tüketiciler arasındaki doğrudan ortaklıktır; burada toplum üyeleri, hasadın bir kısmı karşılığında bir çiftliği finansal olarak desteklerler. Birden fazla aracının yer aldığı geleneksel gıda tedarik zincirlerinin aksine, TDT çiftçiler ve tüketiciler arasında şeffaflık, güven ve riski paylaşımını teşvik eder (Sulistyowati ve ark., 2023). Bu modelde mevsimlik ürünler için tüketiciler çiftçilere tohum, ekipman gibi tarımsal girdilere yatırım yapmak için ön ödeme yapmayı taahhüt eder finansal belirsizliği azaltırlar (Cechin ve ark., 2021).

Bu düzenleme ayrıca, pasif alıcılar yerine gıda üretiminde aktif katılımcılar haline gelen tüketiciler arasında bir sorumluluk ve katılım duygusunu da teşvik eder. Bazı TDT modelleri, tüketici üyeleri ekim, hasat ve dağıtım dahil olmak üzere doğrudan çiftlik faaliyetlerine dahil ederek üretici-tüketici bağlantısını daha da güçlendirmektedirler (Takagi vd., 2024). Ayrıca TDT, hem çiftçiler hem de tüketiciler için adil bir fiyatlandırmayı teşvik ederek endüstriyel tarımın aşırı yüksek fiyatlandırma yapılarından uzaklaşır (Degens ve ark., 2023).

Küçük Ölçekli Çiftçiliği ve Topluluk Dayanışmasını Güçlendirme

TDT, genellikle endüstriyel tarım işletmelerine karşı rekabet etmekte zorlanan küçük ölçekli çiftçileri desteklemede önemli bir rol oynar. TDT, istikrarlı bir müşteri tabanı sağlayarak ve piyasa belirsizliklerini azaltarak küçük çiftçilere piyasa dalgalanmalarına karşı finansal güvenlik ve dayanıklılık sağlar (Egli ve ark., 2023). Araştırmalar, TDT çiftliklerinin uzun vadeli çiftlik sürdürülebilirliğine ve çevresel yöneticiliğe katkıda bulunan tarımsal ekolojik uygulamaları, ürün çeşitlendirmesini ve sürdürülebilir arazi yönetimini uygulama olasılığının endüstriyel işletmelere göre daha yüksek olduğunu göstermektedir (Sulistyowati ve ark., 2023).

Ekonomik faydaların ötesinde, TDT daha güçlü toplum bağlarını teşvik ederek tüketiciler ve üreticiler arasında dayanışma ağları oluşturur. TDT gruplarının üyeleri genellikle çiftlik ziyaretleri, eğitim atölyeleri ve toplum etkinlikleri düzenleyerek gıda üretimi ve çevre koruma konusunda kolektif bir sorumluluk duygusunu güçlendirir (Takagi ve ark., 2024). Topluluk odaklı bu yaklaşım, tüketicilerin gıda kaynaklarından koptuğu endüstriyel gıda sistemlerinin neden olduğu yabancılaşmanın önlenmesine de yardımcı olur (Voge ve ark., 2023).

Yerel ve Mevsimlik Üretimin Teşviki

TDT'nın temel ilkelerinden bir diğeri yerel ve mevsimlik gıda üretimine vurgu yapmak, uzun mesafeli taşımacılık ve büyük ölçekli gıda dağıtımıyla ilişkili çevresel ayak izini azaltmaktır. TDT, gıdayı yerel olarak tedarik ederek gıda tedarik zincirinin uzunluğundan kaynaklanan karbon emisyonlarını en aza indirir, bölgesel gıda ekonomilerini destekler ve yerel gıda güvenliğini artırır (Cechin ve ark., 2021).

Ayrıca, TDT üyeleri beslenme alışkanlıklarını mevsimsel bulunabilirliğe göre ayarlayarak biyolojik çeşitliliği ve ekolojik dengeyi teşvik eder. Tek kültüre ve yıl boyunca bulunabilirliğe öncelik veren endüstriyel tarımın aksine, TDT yerel iklimlere uyarlanmış, çeşitli, besin açısından zengin ürünlerin tüketimini teşvik eder (Takagi ve ark., 2024). Tüketiciler ayrıca geleneksel çiftçilik bilgisi ve sürdürülebilir yetiştirme uygulamalarına daha fazla değer verir ve tüketim modellerinde uzun vadeli değişimleri teşvik eder (Fomina ve ark., 2022).

Ekonomik, Sosyal ve Çevresel Sürdürülebilirlik

TDT, ekonomik, sosyal ve çevresel hususları tek bir çerçeveye entegre ederek bütünsel sürdürülebilirlik için bir model görevi görür.

Ekonomik Sürdürülebilirlik: TDT, üretim başlamadan önce garantili satışlar sağlayarak çiftçilere finansal istikrar sağlar ve dalgalanan piyasa fiyatlarına olan bağımlılığı azaltır (Egli ve ark., 2023). Çalışmalar, TDT çiftliklerinin, özellikle kooperatif veya toplum destekli çerçeveler içinde faaliyet gösterdiklerinde, geleneksel küçük çiftliklere göre daha yüksek ekonomik uygulanabilirliğe sahip olma eğiliminde olduğunu göstermektedir (Cechin ve ark., 2021).

Sosyal Sürdürülebilirlik: TDT modeli, düşük gelirli tüketiciler için maliyet dengeleme programları sunarak ekonomik boşlukları kapatmaya yardımcı olarak toplumsal dayanıklılığı ve kapsayıcılığı teşvik eder (Jilcott Pitts ve ark., 2022). Ancak, üyelik ücretleri bazı haneler için engelleyici olabileceğinden (Takagi ve ark., 2024), TDT'nın düşük gelirli gruplara erişilebilirliği konusunda zorluklar devam etmektedir.

Çevresel Sürdürülebilirlik: Endüstriyel tarımla karşılaştırıldığında, TDT çiftlikleri daha yüksek kaynak verimliliği, daha düşük sera gazı emisyonları ve iyileştirilmiş toprak sağlığı göstermektedir (Egli ark., 2023). Birçok TDT girişimi, uzun vadeli ekolojik dengeye katkıda bulunan permakültür ilkelerini, organik çiftçiliği ve düşük girdili tarım tekniklerini uygulamaktadır (Sulistyowati ve ark., 2023).

Topluluk Destekli Tarımın (TDT) Faydaları

Topluluk Destekli Tarım (TDT) ekonomik, sosyal ve çevresel faydalar sunarak endüstriyel gıda sistemlerine uygulanabilir bir alternatif olarak ortaya çıkmıştır. Çiftçiler ve tüketiciler arasında doğrudan ortaklıklar kuran TDT, yerel ekonomileri güçlendirir, küçük ölçekli çiftçileri destekler ve sürdürülebilir tarım uygulamalarını teşvik eder. Bu bölümde küçük çiftçileri desteklemeye, ekonomik ve sosyal etkilere ve çevresel sürdürülebilirliğe odaklanarak TDT'nın temel faydalarını incelenecektir.

Küçük Ölçekli Çiftçileri Destekleme

TDT'nın temel avantajlarından birisi küçük ölçekli çiftçilere ekonomik istikrar sağlayarak onları piyasa oynaklığından ve endüstriyel rekabetten koruma yeteneğidir. Karların dalgalanan toptan fiyatlar tarafından belirlendiği geleneksel piyasa tabanlı üreticiliğin aksine TDT çiftçileri üye tüketicilerden peşin ödemeler alarak öngörülebilir bir gelir sağlamış olur ve bu da tarımsal üretimle ilişkili finansal riskleri azaltır (Cechin ve ark., 2021). Ek olarak, TDT gelir akışlarını çeşitlendirerek çiftlik dayanıklılığını da artırır. Birçok TDT çiftliği, fazla ürünlerini piyasaya satabilir veya üretici pazarlarına katılır veya gelirlerini desteklemek için bazı eğitim programları sunabilir (Tay ve ark., 2024). Bu model küçük ölçekli çiftçilerin tarımsal ekolojik uygulamaları benimsemelerine, ürün çeşitliliğine odaklanmalarına ve verimi maksimize etme baskısı altında kalmadan sürdürülebilirlik adına uzun vadeli yatırımlar yapmalarına olanak tanır (Egli ve ark., 2023).

TDT ayrıca küçük ölçekli çiftçilere güçlü tüketici ilişkileri kurarak doğrudan iletişimi teşvik ederek ve üreticiler ile tüketiciler arasında güven ve sadakat duygusu yaratmaya yardımcı olur (Voge ve ark., 2023). Bu kişisel bağlantı TDT çiftçilerinin değişken dış alıcılar yerine kendi üyelerine güvenmeleri nedeniyle piyasa bağımlılığını azaltır.

Ekonomik, Sosyal ve Çevresel Etkiler

Ekonomik Etkiler

TDT, sermayeyi büyük tarım işletmelerine yönlendirmek yerine topluluklar içinde tutarak yerel ekonomilere önemli ölçüde katkı sağlar (Medici ve ark., 2021). Çalışmalar TDT üyelerinin genellikle yerel gıdaya daha fazla harcama yaptığını ve üretici pazarları ve yerel esnaf ve zanaatkar gibi tamamlayıcı işletmeleri desteklediğini göstermektedir (Egli ve ark., 2023).

TDT çiftlikleri ayrıca pazarlama ve ulaşım maliyetlerini azaltarak çiftçilerin finansal güvenliğini de iyileştirir. Doğrudan tüketiciye yönelik modeller aracıları ortadan kaldırarak çiftçilerin nihai satış fiyatından daha büyük bir pay almasını sağlarken üyelere rekabetçi fiyatlarla yüksek kaliteli ve taze gıda sunar (Sulistyowati ve ark., 2023).

Dahası, TDT iş yaratma potansiyeliyle kırsal kalkınmada da rol oynar. Çalışmalar TDT çiftliklerinin endüstriyel çiftliklere kıyasla daha fazla yerel işgücü istihdam ettiğini ve adil ücretler sağladığını ve kırsal alanlarda ekonomik istikrara katkıda bulunduğunu göstermektedir (Sulistyowati ve ark., 2023).

Sosyal Etkiler

TDT gıda ve tarım sürdürülebilirliği konusunda tüketiciler ve çiftçilerden oluşan ağlar oluşturarak toplumsal katılımı ve sosyal uyumu teşvik eder. Tüketicilerin doğrudan bağlantılarının olmadığı geleneksel gıda sistemlerinin aksine TDT çiftlik ziyaretleri, eğitim atölyeleri ve gönüllü programları aracılığıyla katılımı teşvik eder (Jilcott Pitts ve ark., 2022).

TDT'ya katılım üyelerin mevsimsel beslenme, sürdürülebilir tarım uygulamaları ve yerel çiftçileri desteklemenin sosyal değeri konusunda daha fazla farkındalık bildirmesiyle artan gıda okuryazarlığıyla ilişkilendirilmiştir (Fomina ve ark., 2022). Çalışmalar ayrıca TDT üyelerinin daha fazla taze ürün tükettikleri ve işlenmiş gıdalara olan bağımlılıklarını azalttıkları için artan bir refah seviyesi ve iyileşen beslenme alışkanlıkları yaşadıklarını göstermektedir (Sulistyowati ve ark., 2023).

Ancak burada erişilebilirlik bir zorluk olmaya devam etmektedir. Birçok TDT programı hala öncelikli olarak orta ila üst gelir gruplarına hizmet etmekte ve düşük gelirli toplulukların katılımını sınırlamaktadır. Bu sorunu çözmek için bazı TDT çiftlikleri ekonomik olarak dezavantajlı grupların taze gıdaya daha kolay ulaşmasını sağlamak amacıyla maliyet dengeleme ve sübvansiyon programları başlatmaktadırlar (Egli ve ark., 2023).

Çevresel Etkiler
TDT çiftlikleri sentetik gübreler, pestisitler ve fosil yakıt yoğunluklu taşımacılık gibi endüstriyel tarımsal girdilere olan bağımlılığı azaltarak çevresel sürdürülebilirliğe katkıda bulunmaktadırlar. Geleneksel çiftçilikle karşılaştırıldığında TDT operasyonlarının şunları sağladığı gösterilmiştir:
Gıda tedarik zincirini azaltarak nakliye maliyetlerini en aza indirip sera gazı emisyonlarını azaltmak (Egli ve ark., 2023).
Ürün rotasyonu, kompostlama ve organik çiftçilik yöntemleriyle toprak sağlığını iyileştirmek (Tay ve ark., 2024).
Endüstriyel monokültürlerin aksine, polikültür ve miras ürün çeşitlerini teşvik ederek biyoçeşitliliği artırmak (Voge ve ark., 2023).
"Kusurlu" ancak yenilebilir ürünlerin değerli olduğu doğrudan tüketiciye dağıtımı sağlayarak gıda israfını azaltmak (Medici ve ark., 2021).
TDT ayrıca üyelerin sürdürülebilir çiftçilik konusunda daha derin bir anlayış geliştirmesi ve çevre dostu gıda seçimlerine aktif olarak katılmasıyla tüketiciler arasında çevre bilincini de teşvik eder (Jilcott Pitts ve ark., 2022).

Başarılı TDT Uygulamaları ve Başlıca Özellikleri

Topluluk Destekli Tarım (TDT) üretici-tüketici ortaklıkları ve sürdürülebilir tarımsal üretimin temel ilkelerini koruyarak bu modeli yerel koşullara uyarlayan çeşitli bölgelerde başarıyla uygulanmıştır. İsviçre'de, Avrupa'nın en eski TDT'larından biri olan Les Jardins de Cocagne, topluluk katılımını ve finansal sürdürülebilirliği artırmak için bir iş paylaşımı bileşenini dahil ederek yaklaşık 400 üyeye başarılı bir şekilde organik sebze sağlamaktadır (Medici ve ark., 2023). Benzer şekilde Fransa'da AMAP (Association de Maintien de l'Agriculture Paysanne) ağı, çiftçiler için adil bir gelir sağlarken gıda egemenliğini güçlendirerek doğrudan çiftçi-tüketici ilişkilerini teşvik eder (Medici ve ark., 2023). Almanya'da Solidarische Landwirtschaft modeli çevresel kaygılara yanıt olarak ortaya çıktı ve daha zengin üyelerin daha düşük gelirli katılımcıları sübvanse ettiği ve daha fazla kapsayıcılık sağlayan dayanışma temelli finansal yapıları içermekterdir (Medici ve ark., 2023).

Amerika Birleşik Devletleri genelinde TDT çiftlikleri daha geniş bir tüketici tabanına ulaşmak için abonelik tabanlı satışları, eğitim programlarını ve kademeli fiyatlandırmayı entegre ederek ürün çeşitlendirmesine ve finansal istikrara vurgu yapmaktadır (Tay ve ark., 2024). Bu arada Kanada'da "Aile Çiftçileri Ağı" ile her yıl 20.000'den fazla aileye tedarik sağlayarak yerel gıda dağıtımını kolaylaştıran ve küresel tedarik zincirlerine olan bağımlılığı azaltan iyi yapılandırılmış bir TDT sistemi kurulmuştur (Medici ve ark., 2023). Japonya'da, en eski TDT modellerinden biri olan Teikei hareketi, organik çiftçiliğe ve karşılıklı yardıma vurgu yaparak çiftçiler ve tüketiciler arasında doğrudan, uzun vadeli ortaklıklar sağlayarak gelişmeye devam etmektedir (Tay ve ark., 2024). Çin'de, TDT'lar gıda güvenliğini ve kırsal kalkınmayı artırmak için STK desteği ve hükümet katılımını birleştirerek kentsel-kırsal kooperatif ağlarını entegre etmektedirler (Medici ve ark., 2023). Benzer şekilde, Brezilya TDT modelleri atık azaltımına ve ekolojik sürdürülebilirliğe vurgu yaparak gıda israfını en aza indirmek için besin değerine odaklanmaktadır (Tay ve ark., 2024). Avustralya'da da TDT'lar özellikle uygun maliyetli organik gıda sağlamada başarılı olmuş ve yerel olarak desteklenen tarımın verimli bir şekilde yapılandırıldığında geleneksel süpermarketlerden daha uygun fiyatlı olabileceğini kanıtlamıştır (Tay ve ark., 2024). Danimarka'nın Aarstiderne TDT'sı, TDT modeline yemek planlama ve tarif entegrasyonunu dahil ederek benzersiz bir yaklaşım benimsemiş ve tüketicilerin gıda paylarını tam olarak kullanmalarını kolaylaştırırken Danimarka'da 50.000'den fazla ve İsveç'te 10.000'den fazla aboneyi desteklemiştir (Medici ve ark., 2023). Bu örnekler, TDT'nın küresel uyarlanabilirliğini ortaya koyarak, modelin sürdürülebilirlik, ekonomik dayanıklılık ve toplum katılımı gibi temel ilkelerini korurken farklı ekonomik ve çevresel bağlamlara nasıl uyarlanabileceğini göstermektedir.

Topluluk Destekli Tarımın sıralanan faydalarına rağmen karşılaşılan çeşitli zorluklar yaygın olarak benimsenmesini ve uzun vadeli sürdürülebilirliğini engellemektedir. En önemli sorunlardan biri birçok tüketicinin mevsimsel değişkenlik ve öngörülemeyen ürün bulunabilirliğinden kaynaklanan memnuniyetsizlikler nedeniyle uzun vadeli üye katılımı nı sürdürmekte zorlanmasıdır (Sulistyowati ve ark., 2023). Ek olarak TDT üyelik ücretleri yüksek olabilir ve düşük gelirli hanelerin katılımını zorlaştırabilir bu da ekonomik erişilebilirlik açısından önemli bir engel olmaya devam etmektedir. Bazı TDT girişimleri, kademeli fiyatlandırma, sübvansiyonlar ve bağış tabanlı modeller uygulayarak bunu hafifletmeye çalışsa da finansal kapsayıcılık bir zorluk olmaya devam etmektedir (Tay ve ark., 2024). Bir diğer kritik engel ise artık organik ve yerel gıdalara genellikle rekabetçi fiyatlarla kolay erişim sağlayan süpermarketler ve çevrimiçi market teslimat hizmetlerinin oluşturduğu rekabettir. Bu rekabet, TDT programlarının özellikle alternatif gıda kaynaklarının bol olduğu kentsel alanlarda üye çekmesini ve elde tutmasını zorlaştırmaktadır (Sulistyowati ve ark., 2023). Ek olarak, idari ve işgücü zorlukları yalnızca ürün üretimini yönetmekle kalmayıp aynı zamanda lojistik, müşteri ilişkileri ve finansal planlama gibi görevleri de üstlenmek zorunda olan çiftçilere önemli yükler getirmektedir (Jilcott Pitts ve ark., 2022). Bazı ülkelerde yasal tanınma ve politika desteğinin eksikliği birçok girişimin etki alanlarını genişletmek için fon, arazi erişimi ve kurumsal destek

sağlamakta zorlanması nedeniyle TDT operasyonlarını daha da karmaşık hale getirmektedir (Medici ve ark., 2023). Dahası, aşırı hava olayları, kuraklıklar ve değişen büyüme mevsimleri hasatları aksatabileceği ve genel gıda güvenliğini azaltabileceği için iklim değişikliği ve çevresel faktörler ek tehditler oluşturmaktadır ve bu da TDT çiftçilerinin üyelere tutarlı paylar teslim etmesini zorlaştırmaktadır (Medici ve ark., 2023). Bu zorlukların ele alınması, TDT'nın sürdürülebilir ve kapsayıcı bir gıda sistemi modeli olarak gelişmeye devam edebilmesini sağlamak için daha güçlü politika desteği, finansal teşvikler ve farkındalık oluşturma girişimleri gerektiriyor.

Türkiye'de Toplum Destekli Tarım olarak bilinen Topluluk Destekli Tarım, özellikle gıda güvenliği endişelerine ve endüstriyel tarımın artan hakimiyetine yanıt olarak alternatif bir gıda üretim ve dağıtım modeli olarak ilgi görmektedir (Yıldız ve Zengin, 2020). Türkiye'de merkezi bir TDT ağı bulunmamakla birlikte, öncelikle İstanbul-Antalya kıyı bölgesi ve Ankara'da yoğunlaşan çeşitli gıda toplulukları ve ekolojik pazarlar ortaya çıkmıştır (Öncel ve Akkaya, 2024). TDT uygulamasının kayda değer örneklerinden biri, küçük ölçekli üreticileri kentsel tüketicilerle başarılı bir şekilde birbirine bağlayan, dayanışma ekonomilerini ve sürdürülebilir gıda uygulamalarını teşvik eden Batı İzmir Topluluk Destekli Tarım Girişimi'dir (BİTOT) (Demircan Yıldırım, 2024). Ek olarak, mantar yetiştiriciliğinin TDT modellerine entegre edilmesi ve mantar yetiştiriciliğinin yıl boyu üretim ve pazar istikrarı sağlaması ve onu TDT odaklı gıda sistemleri için uygun bir seçim haline getirmesi nedeniyle uygulanabilir bir tarımsal girişimcilik fırsatı olarak önerilmiştir (Öncel ve Akkaya, 2024). Ayrıca TDT, kooperatif tabanlı gıda sistemlerinin kapitalist ve endüstriyel gıda pazarına bir alternatif sunduğu Emile Durkheim'ın kolektif dayanışma kavramıyla uyumlu bir sosyal inovasyon aracı olarak kabul edilmiştir (Köleoğlu ve ark., 2022). Özellikle finansal sürdürülebilirlik, tüketici katılımı ve düşük gelirli gruplar için erişilebilirlik konusunda zorluklar devam etmektedir (Kanbak, 2024). Bu engellere rağmen, Türkiye'deki TDT, tabandan gelen girişimler, kooperatif ağları ve yerel ve sürdürülebilir gıda üretimine yönelik artan tüketici ilgisi yoluyla genişlemeye devam ederek, kendisini gıda güvenliği ve sürdürülebilirliğinin geleceği için umut verici bir model olarak konumlandırmaktadır.

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Effects of Pseudocereals and Germination on Gut Microbiota

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Abstract

This study examines the effects of consuming pseudocereals (amaranth, buckwheat, quinoa, and chia), which are gluten-free and exhibit grain-like properties, on gut health and the gut microbiota. Due to their high dietary fiber and bioactive compound content, pseudocereals can contribute to balancing the gut microbiota, promoting the growth of probiotic bacteria, and suppressing pathogenic microorganisms. The study also discusses the effects of germination, which enhances the nutritional value of grains, reduces antinutritional factors, improves mineral absorption, and increases antioxidant capacity.

The prebiotic effects of pseudocereals are important for maintaining a healthy gut microbiota, regulating the digestive system, and strengthening the intestinal barrier. In particular, the increased production of short-chain fatty acids (SCFAs) provides an energy source for the gut epithelium and supports mucosal integrity. With these properties, pseudocereals emerge as alternative food sources for individuals with celiac disease and gluten intolerance.

In the literature, the health benefits of pseudocereals have been associated with hepatoprotective, anti-inflammatory, antihypertensive, and anticancer effects. However, long-term dietary experiments and clinical studies are needed to evaluate these effects in more detail. The studies suggest that consuming pseudocereals, particularly in germinated form, may benefit gluten-free diets and improve gut health.

Keywords: *Pseudocereals, germination, gut microbiota, dietary fiber, prebiotic, gluten intolerance, SCFA, antioxidant.*

Psödotahıllar ve Çimlendirmenin Bağırsak Mikrobiyotasına Etkileri

Özet

Bu derleme çalışması, gluten içermeyen ve tahıllara benzer özellikler gösteren psödotahılların (amarant, karabuğday, kinoa ve chia) tüketiminin bağırsak sağlığı ve bağırsak mikrobiyotası üzerindeki etkilerini incelemektedir. Psödotahıllar, yüksek diyet lifi ve biyoaktif bileşen içeriği sayesinde, bağırsak mikrobiyotasının dengelenmesine, probiyotik bakterilerin çoğalmasına ve patojen mikroorganizmaların baskılanmasına katkıda bulunabilmektedir. Çalışmada, çimlendirme işleminin, tanelerin besin değerini artırdığı, antibesinsel maddeleri azalttığı ve mineral emilimini iyileştirdiği; bunun yanı sıra antioksidan kapasitenin yükseltilmesine olan etkileri de ele alınmıştır.

Bağırsak mikrobiyotasının sağlıklı yapısının korunması, sindirim sisteminin düzenlenmesi ve bağırsak bariyerinin güçlendirilmesi açısından, psödotahılların prebiyotik etkileri önem arz etmektedir. Özellikle kısa zincirli yağ asitlerinin (SCFA) üretiminin artması, bağırsak epiteli için enerji kaynağı sağlamakta ve mukozal bütünlüğü desteklemektedir. Bu özellikleriyle psödotahıllar, çölyak hastaları ve gluten intoleransı bulunan bireyler için alternatif besin kaynakları olarak öne çıkmaktadır.

Literatürde, psödotahılların sağlığa katkıları; hepatoprotektif, antiinflamatuar, antihipertansif ve antikanserik etkilerle ilişkilendirilmekte olup, uzun süreli beslenme deneyleri ve klinik çalışmalarla bu etkilerin daha detaylı değerlendirilmesi gerekmektedir. Yapılan çalışmalar psödotahılların ve çimlendirilerek tüketiminin, glütensiz diyetlerin zenginleştirilmesinde ve bağırsak sağlığının iyileştirilmesinde potansiyel olarak faydalı olabileceğini göstermektedir.

Anahtar Kelimeler: *Psödotahıllar, çimlendirme, bağırsak mikrobiyotası, diyet lifi, prebiyotik, gluten intoleransı, SCFA, antioksidan.*

Giriş

Günümüzde daha çok gluten intoleransının yaygınlaşması ve bağırsak tahribatına neden olduğu düşünülen gluten içeren tahıllara alternatif olarak psödotahılların tüketimi ön plana çıkmaktadır. Kinoa, karabuğday, chia tohumu ve amarant bunlara örnek verilebilir. Türkiye'de psödotahıl üretimi kısıtlıdır. Ancak, son yıllarda psödotahılların

yetiştiriciliğinde belirgin bir artış gözlemlenmektedir. Özellikle ufak ve orta büyüklükteki çiftçilere verilen destekler ve teşviklerle psödotahıl yetiştiriciliğinin yaygınlaştırılması amaçlanmaktadır (TÜBER, 2022).
Psödotahıllar; amino asitler, antioksidanlar, flavonoidler, polifenoller, mineraller, vitaminler, lignanlar, lif ve doymamış yağ asitleri gibi çeşitli biyoaktif bileşenler bakımından zengindir (İmre ve Işık, 2024). Son yıllarda çimlendirilmiş psödotahıl tüketiminin kullanımı da ön plana çıkmaktadır. Literatürde, çimlendirme ile tanede besin içeriğinin, toplam polifenolik madde içeriğin ve antioksidan aktivitenin iyileştiği, antibesinsel faktörlerin ise azaldığı bildirilmiştir. Çimlendirmenin başlıca avantajlarından biri, yenilebilir tohumların besin değerini artırmak için kolay uygulanabilen ve ileri düzeyde ekipman gerektirmeyen bir yöntem olmasıdır. (Olcay ve Demir, 2022). Bu derleme çalışmasında psödotahılların ve çimlendirilerek tüketiminin bağırsak mikrobiyotasına etkilerinin incelenmesi amaçlanmaktadır.

Psödotahıllar ve Özellikleri

Psödotahıllar, yapısal olarak gerçek tahıllarla benzerlik gösteren ve yüksek oranda nişasta içeren, çift çenekli bitki türlerine ait tüketilebilir tohumlardır. Bu tohumlar sıcak iklimlerden serin iklim koşullarına kadar çok sayıda ortama uyum sağlayabilen ve yüksek genetik çeşitlilikleri ile gelecekte önemli gıda kaynakları olabilecek ürünlerdir (Joshi vd., 2019). En bilinen çeşitleri kinoa, amarant, chia ve karabuğdaydır (Martinez-Villaluenga vd., 2020). Psödotahıllar genellikle mısır, buğday ve pirinçle karşılaştırıldığında daha yüksek protein ve lipit içeriğine ve daha düşük karbonhidrat içeriğine sahiptir. Tahıl tanelerinin aksine, psödotahıllar diyet lifi, mineraller, vitaminler, lignanlar, flavonoidler, polifenoller, fitosteroller, antioksidanlar ve doymamış yağ asitleri ve dengeli amino asit bileşimi, yüksek sindirilebilirlik ve biyoyararlanım içeren yüksek kaliteli proteinler dahil olmak üzere biyoaktif bileşikler açısından zengindir(Giménez-Bastida vd., 2017). Bu zengin bileşim nedeniyle, psödotahıllar hepatoprotektif, antiinflamatuar, antihipertansif, antikanser ve hipolipidemik özellikler ve obezite ve diyabet için faydalar dahil olmak üzere çeşitli sağlık yararları ile bağlantılıdır (Shahbaz vd., 2022). Ek olarak, psödotahıllar glütensizdir ve bu da onları glütensiz formülasyonlarda kullanım için popüler hale getirir (Niro vd., 2019).
Amarant ve kinoa tohumlarında, nişasta açısından zengin perispermi çevreleyen dairesel bir embriyo (ruşeym) bulunur. Tohum kabuğu ve nispeten daha fazla yağ ve protein içeren kepek kısmı bu yapıyı oluşturur. Amarant ve kinoada kepek oranı (tohum kabuğu ve embriyo), mısır ve buğday gibi tahıllara kıyasla daha yüksek olduğundan, bu bitkilerin protein ve yağ içerikleri de daha fazladır. Karabuğday tohumlarında ise nişasta, endospermde birikir ve çift çenekli embriyo, nişasta içeren endosperm boyunca uzanır. Yalancı tahılların besin bileşimi ile buğdayın bazı besin öğeleri Çizelge 1'de karşılaştırılmıştır (Olcay & Demir, 2022).

Çizelge 1. Psödotahıllar ve Buğdayın Bileşimi (Alvarez-Jubete vd., 2009).

	Amarant	Kinoa	Karabuğday	Buğday
Protein (%)	16.5	14.5	12.5	12.0
Yağ (%)	5.7	5.2	2.1	2.5
Toplam Nişasta (%)	61.4	64.2	58.9	63.0
Diyet Lifi (%)	20.6	14.2	29.5	17.4
Kül (%)	2.8	2.7	2.1	1.5
Kalsiyum (mg $100g^{-1}$)	180.1	32.9	60.9	34.8
Magnezyum (mg $100g^{-1}$)	279.2	206.8	203.4	96.4
Çinko (mg $100g^{-1}$)	1.6	1.8	1.0	1.2
Demir (mg $100g^{-1}$)	9.2	5.5	4.7	3.3

Psödotahıllarda bulunan biyoaktif bileşenler fenolik asitler, flavonoidler (flavonoller, flavonlar, izoflavonlar, flavanonlar ve antosiyanidinler), lignanlar ve stilbenler olmak üzere dört ana gruba ayrılmaktadır. Bu bitkilerde tespit edilen temel biyoaktif bileşenler Çizelge 2'de gösterilmektedir (Pang vd., 2018).

Çizelge 2. Psödotahılların Biyoaktif Bileşenleri (Thakur vd., 2021; Sofi vd., 2022; Skrovankova ve Mlcek, 2020)

Amarant	Kinoa	Karabuğday	Chia
Karetonoidler	**Flavonoidler**	**Flavanoidler:**	**Flavanoidler:**
Zeaksantin	Kuersetin	Rutin (Kuersetin-3-Rutinosid)	Kuersetin
B-Karoten	Kaempferol	**Fenolik Bileşenler**	Kaempferol 3-O-glikozid
Lutein	Mirisetin	P-Hidroksil Benzoik	Epikateşin
Betaline	İzorhamnetin	Siringik Asit	Rutin
Amarantin	**Fenolik Bileşikler**	Vanilik Asit	**Fenolik Bileşenler**
Betasiyaninler	Ferulik Asit-4-Glikozit	Gallik Asit	P-Kumarik Asit
	Betalainler	Protokatekuik Asit	Kafeik Asit
	Betanin	Ferulik Asit P-Kumarik Asit	Klorojenik Asit

Çölyak Hastalığı

Çölyak hastalığı, dünya genelinde en yaygın görülen gıda duyarlılıklarından birisidir. Genetik eğilimi olan bireylerde, gluten içeren tahılların tüketimiyle tetiklenen otoimmün bir sindirim sistemi hastalığıdır. Çölyak hastalarında gluten tüketimi, bağırsak mukozasında sürekli olarak yapısal tahribata yol açar ve ancak glutenin tamamen beslenmeden çıkarılmasıyla mukoza dokusu kendini onarabilir (Fasano ve Catassi, 2001; Alvarez-Jubete vd., 2009). Bağırsak mukozasında oluşan bu zarar sonucunda, besin ögelerinin yeterli düzeyde emilememesi, sindirim sistemi işlev bozuklukları ve mide-bağırsak belirtileriyle ilişkili beslenme yetersizlikleri sıkça ortaya çıkmaktadır (See ve Murray, 2006; Alvarez-Jubete vd., 2009). Buna ek olarak, çölyak hastalığına bağlı olarak bireylerde kansızlık, bağırsak rahatsızlıkları ya da kemik erimesi gibi farklı semptomlar görülebilir (McGough ve Cummings, 2005; Alvarez-Jubete vd., 2009). Gluten içermeyen bir beslenme programı uygulandığında, çölyak hastalarında belirtilerin hafiflediği ve bağırsak dokusunun iyileştiği gözlemlenmiştir (Olcay ve Demir, 2022).

Çimlendirme ve Islatma

Glutensiz beslenme düzeni, gıdalara yüksek besin, mikro besin, fitokimyasal ve lif içeriği olan ürünler eklenerek daha zengin hale getirilebilir. Bir diğer yöntem ise glutensiz diyetlerde filizlendirilmiş yalancı tahılların kullanılmasıdır. Bilimsel kaynaklar, filizlendirmenin tanelerin besin değerini, toplam polifenol miktarını ve antioksidan etkisini artırdığını, istenmeyen besin faktörlerini ise azalttığını göstermektedir. Filizlendirmenin önemli bir avantajı, yenilebilir tohumların besin kalitesini artırmak için basit ve herhangi bir ekipman gerektirmeyen bir işlem olmasıdır (Omary vd., 2012).

Çimlenme süresinin kinoa tohumlarındaki antioksidan konsantrasyonlarını nasıl etkilediğini araştırmak için yapılan bir çalışmada (Carciochi vd., 2016) çimlenmeden 72 saat sonra tokoferol ve askorbik asit içeriğinde çimlenmeyen tohumlara kıyasla önemli bir artış ($p \leq 0,05$) gözlemlenmiştir. Ayrıca çimlenme ile kinoa tohumlarının antioksidan aktivitesinde ve genel fenolik bileşenlerinde önemli bir iyileşme olduğu görülmüştür.Benzer şekilde, çimlenmenin, hidrotermal işlem ve işlemenin karabuğdaydaki demir içeriğine etkisini inceleyen bir çalışmada (Pongrac vd., 2016), sitrat ve fitatın karabuğdaydaki başlıca demir şelatlayıcı maddeler olarak tanımlandığı, özellikle filizlenme sırasında fitat seviyelerinin düştüğü ve bunun sonucunda demir biyoyararlanabilirliğinde bir artış gözlemlendiği bulunmuştur. Kinoa ve karabuğday tohumlarının çimlenmesi, antioksidan konsantrasyonlarını, demir bulunabilirliğini ve biyoaktif bileşik sentezini artırarak glütensiz ürünlerin besin kalitesini iyileştirdiği bildirilmiştir.

Amarant tanelerinin çimlenmesi ile ilgili yapılan araştırmada ise (Rahman vd., 2023) çimlendirmenin besin değerlerini önemli ölçüde artırdığı, daha yüksek protein, antioksidan ve diyet lifi sağlarken, fitik asit ve tanenleri azalttığı görülmüştür. Ek olarak, çimlenme, palmitik asit içeriğini azaltırken, oleik ve linoleik asit gibi çoğu temel amino asit ve faydalı yağ asitlerinin seviyelerini iyileştirmiştir. Amarant ve karabuğdayda çimlendirmenin fenolik içeriklere olan etkisinin araştırıldığı bir araştırmada (Cornejo vd., 2019) ise 24 saatlik çimlenmeden sonra amarant tanelerindeki fenolik içerikte %212,98'lik bir artış gözlemlemiştir. Karabuğdaydaki fenolik içerik, çiğ tanelerdeki 210,31 mg GAE/100 g'dan, çimlenmeden 72 saat sonra 473,98 mg GAE/100 g'a önemli ölçüde artarak %125,32'lik bir artışı temsil etmiştir. Genel olarak, çimlenme, yalancı tahılların besinsel ve işlevsel özelliklerini artırarak onları sağlık için daha faydalı hale getirmiştir (Reddy et al., 2024).

Diyet Lifleri

Diyet lifi, ağırlıklı olarak tahıllar, meyveler ve sebzelerde bulunan önemli bir besin bileşenidir. Diyet lifleri farklı şekillerde sınıflandırılsa da en yaygın kullanılan yöntem, çözünürlüklerine göre yapılan sınıflamadır. Diyet lifleri, bir tür sınıflandırmadır. Meyve ve sebzelerde bulunan diyet lifleri, özellikle tahıllarda (buğday, arpa, yulaf, pirinç, çavdar) ve psödotahıllarda (chia, kinoa, karabuğday, amarant) yoğun olarak bulunur (Cingöz vd., 2022).

Diyet liflerinin sağlığa yararları, suda çözünebilme özelliklerine bağlıdır. Suda çözünen diyet lifleri, ince bağırsağa ulaştığında suyla birleşerek jelimsi bir yapı oluşturur ve besinlerin ince bağırsaktaki ilerleyişini yavaşlatır. Bu sayede besin maddelerinin emilimi daha uzun sürer ve yiyeceklerdeki şeker ve yağ asitlerinin kana karışması gecikir. Ek olarak, jel kıvamına gelen çözünen diyet lifleri, kolesterol ve yağları bünyesine katarak vücuttan atılmasına yardımcı olur. Suda çözünmeyen diyet lifleri, midede ve ince bağırsakta sindirilmeden ya da jel kıvamına dönüşmeden doğrudan kalın bağırsağa ulaşır. Bu liflerin, kalın bağırsakta sindirimle ortaya çıkan atıkların fermente edilmesi ve bağırsak kas hareketlerinin düzenlenmesi üzerinde olumlu etkileri bulunmaktadır. Ayrıca, dışkının kalın bağırsaktan daha hızlı atılmasını sağlayarak, toksik maddelerin, genetik yapıya zarar verebilecek bileşenlerin ve zararlı kimyasalların bağırsak hücreleriyle temas süresini azaltır ve vücuttan daha kolay atılmasını destekler (Hajishafiee vd., 2016).

Psödotahıllar iyi bir lif kaynağıdır. Karabuğday, yüksek lif içeriği ve düşük çözünür-çözünmez lif oranı ile dikkat çekmektedir. Çeşitli amarant türleri, çözünür lif içeriklerinde farklılıklar göstermektedir. Kinoa, %80'den fazlası çözünmeyen önemli bir lif içeriğine sahiptir (Malleshi vd., 2021). Hem amarant hem de kinoadaki diyet lifinin yaklaşık %22'sine katkıda bulunan arabinoz açısından zengin pektik polisakkaritlerin (%34-55) ve ksiloglukanların (%40) varlığı Gullon ve arkadaşları tarafından 2016'da yürütülen çalışmalarda vurgulanmıştır.

Karabuğday kepeği, fagopiritolleri ile tip II diyabetin tedavisinde potansiyel faydalar sunabilir. Amarantta, pektik polisakkaritler ve ksiloglukanlar, değişen oranlarda birincil lif bileşenlerini oluşturur. Amarantın çözünmeyen

kısmı, çoğunlukla arabinoz ve galakturonik asitten oluşan yüksek konsantrasyonda pektik polisakkarit ve arabinan içerir. Bu fraksiyonda daha düşük seviyelerde ksiloz (%10.4) ve glikoz (%20.1) bulunmuştur (Wefers vd., 2015). Amarantın öncelikle galakturonik asit, arabinoz ve galaktoz, ksiloz ve glikoz gibi çözünmeyen lif bileşenleri içerdiğini göstermiştir (Reddy vd., 2024).

Dünya Sağlık Örgütü (DSÖ) ve Birleşmiş Milletler Gıda ve Tarım Örgütü (FAO) verilerine göre, yetişkin bir bireyin günlük ortalama 25-35 gram lif veya 1000 kcal başına 14 gram lif tüketmesi, 2 yaşından büyük çocukların ise vücut ağırlığının kilogramı başına 0.5 gram lif alması önerilmektedir. Yaş faktöründen bağımsız olarak, erkeklerin kadınlara kıyasla daha fazla lif tüketmesi önerilmektedir (Buil-Cosiales vd., 2016). Hangi tür veya kaynaktan lif alınması gerektiğine dair özel bir öneri bulunmamakla birlikte, günlük lif alımının en az yarısının tam tahıllı gıdalardan sağlanması tavsiye edilmektedir (Evert vd., 2013). Ancak, kültürel değişimler, dışarıda yemek yeme alışkanlığının yaygınlaşması, kentleşme, rafine ve işlenmiş gıdalara yönelim, ekonomik zorluklar ve bilgi eksikliği gibi etkenler nedeniyle dünya genelinde günlük lif tüketimi oldukça düşük seviyededir (Hajishafiee vd., 2016).

Antioksidan Aktivite

Antioksidanlar genellikle "serbest radikal temizleyicileri" olarak adlandırılır. Bu bileşikler oksidasyonu önlemede, enfeksiyon riskini azaltmada, kalp sağlığını desteklemede ve çeşitli kanser ve dejeneratif hastalıkları önlemede rol oynar (Giménez-Bastida vd., 2017). Amarantta, flavonoidler ve fenoliklerin içeriği antioksidan aktivite potansiyeli ile ilişkilidir. Karabuğday hem kabuklarda hem de tohumlarda ve karabuğday ununda bulunan oligomerik proantosiyanidinler gibi flavonoidler de dahil olmak üzere antioksidanlar açısından zengindir. Ek olarak, kanser veya kalp hastalıklarıyla mücadeleye katkıda bulunan koruyucu fenolik bileşikler içerir (Jan vd., 2023). Ayrıca antioksidanlar, DNA'yı hasardan koruyarak ve iltihabı veya kanserli hücrelerin oluşumunu önleyerek vücudun hücresel işlevlerini desteklemede hayati bir role sahiptir (Giménez-Bastida vd., 2017).

Kinoa, anti-obezite, hipokolesterolemik etkiler ve kardiyovasküler hastalıkların önlenmesi gibi çeşitli sağlık yararlarına katkıda bulunan yüksek antioksidan aktivitesi de dahil olmak üzere besinsel özellikleriyle iyi bilinmektedir. Kaempferol, rutin ve kuersetin gibi glikozitler de dahil olmak üzere fenolik bileşikler ve flavonoidler açısından zengindir ve güçlü antioksidan özellikler sağlayarak işlevsel gıda durumunu artırır (Agarwal vd., 2023). Kinoa tohumlarıyla desteklenen bir diyetle ilgili yapılan çalışmada (Pasko vd., 2010), kinoanın plazma malondialdehit düzeylerini düşürerek ve antioksidan enzimlerin aktivitelerini artırarak sıçanlarda oksidatif stresi azalttığı ayrıca kinoa'nın oksidatif hasara karşı koruma ve antioksidan kapasitesini artırdığı bildirilmiştir. Amarant, karabuğday ve kinoa gibi yalancı tahılların antioksidan aktivitesi, oksidatif stresi azaltma, kronik hastalıkları önleme ve genel hücre sağlığını destekleme gibi çeşitli sağlık yararları sağlayan yüksek fenolik bileşik ve flavonoid içeriği nedeniyle önemlidir.

Bağırsak Mikrobiyotası

Yetişkin gastrointestinal sisteminde bulunan bakteriler tipik olarak *Bacteroidetes* , *Firmicutes* , *Actinobacteria* ve *Proteobacteria* gibi dört gruba ayrılabilir . Bacteroides'in anacinsleri *Bacteroides* ve *Prevotella*'dır ve *Clostridium* , *Faecalibacterium* , *Roseburium* , *Ruminococcus* , *Streptococcus* ve *Lactobacillus* gibi bakteriler *Firmicutes'in* ana cinsleridir . Ayrıca, *Bifidobacteria* , *Actinobacteria*'ya ait ana cins iken , *Proteobacteria, Escherichia* gibi *Enterobacteriaceae*'de bulunur (Davenport vd., 2017) . Yukarıda belirtilen bağırsak mikroflorası arasında, *Bacteroidetes* ve *Firmicutes* yetişkinlerde en bol bulunan baskın bakterilerdir (Harmsen ve Goffau, 2016; Ismail vd., 2011).

Bağırsak mikrobiyal ekosistemi oldukça karmaşıktır ancak esnek bir dinamik dengededir ve insan vücudunda bağışıklık sistemi ve iç ortamın homeostazını korumada birçok farklı temel işlevi yerine getirir. Mikrobiyota, insan vücudundaki besinlerin sindiriminde, emiliminde, vitamin ve hormon üretiminde rol oynar. Patojenlerin hayatta kalması için gerekli besinleri tüketebilir veya patojenlerin büyümesini engelleyen moleküller üretebilir (Li vd., 2024).

Diyet, konak ve çevre gibi faktörler mikrobiyotanın bileşiminde ve işlevinde değişikliklere katkıda bulunur. Bu faktörler tarafından mikrobiyota olumsuz etkilendiğinde, bağırsak mikrobiyotası ile insan vücudunun diğer organları arasındaki denge patojen mikroorganizmalar tarafından bozulabilir (Li vd., 2024).

Psödotahılların Bağırsak ve Mikrobiyota Üzerine Etkileri

Prebiyotikler, kolondaki sağlığı geliştirici bakteri popülasyonlarının çoğalmasını aktivitesini destekleyen diyet substratlarıdır (Conlon ve Bird, 2015; Markowiak vd., 2017). Çözünebilir özütler, gıda matrisinin prebiyotiklerinin izolasyon süreciyle elde edilir ve çoğunlukla çözünür liften oluşur. İnülin, rafinoz ve stakiyoz gibi en yaygın kullanılan prebiyotikler, bağırsak bakteri popülasyonlarını desteklemeye yarar sağlayan diyet lifleridir (Sarao ve Arora , 2017). Bağırsak işlevselliğini, bağırsak morfolojisini ve mineral emilimini iyileştirmekten sorumlu olduğu bilinmektedir. Son çalışmalar, bitki tohumu kökenli çözünür özütlerin tüketiminin, sükraz-izomaltaz, aminopeptidaz ve sodyum glikoz kotransporter-1 gibi besinlerin sindirimi ve emilimine katkıda bulunan fırça kenar zarı (BBM) proteinlerini olumlu etkileyebileceğini göstermiştir. Ayrıca, çözünür özütler, mukus üretimi, kadeh hücresi sayısı, kadeh hücresi çapı, villus yüzey alanı, villus yüksekliği, villus genişliği ve kript derinliğini

artırarak bağırsak sağlığını olumlu yönde etkilemektedir. Bu işlevsel ve morfolojik etkiler, çözünür özütler tarafından sindirim sisteminin artan hareketliliğinden dolayı meydana geliyor ve kas hücrelerinin hiperplazisine ve hipertrofisine yol açmaktadır. Ek olarak, bitki kökenli çözünür özüt (yüksek lif içeriği ve dolayısıyla potansiyel prebiyotik özellikler) uygulaması, doğrudan veya dolaylı olarak demir ve çinko biyoyararlanımını artıran bir faktör olarak etki edebilir. Bu olay, alt bağırsak (kolon) lif fermantasyon süreci ve bağırsak pH'ını azaltan, potansiyel olarak patojenik bakteri popülasyonlarının büyümesini engelleyen ve çözünürlüğü ve dolayısıyla minerallerin emilimini artıran kısa zincirli yağ asitlerinin (SCFA'lar) bakteriyel üretimi sonucunda meydana gelir. SCFA'lar diyet minerallerinin emilimine katkıda bulunan emici yüzey alanını artıran epitel hücrelerini çoğaltabilir. Ayrıca, daha önce, çözünür özütlerin tüketiminin, organik asitlerin üretimi yoluyla gastrointestinal mikrobiyal topluluk içindeki metabolik etkileşimleri teşvik ederek sinerjik bir etkiye sahip olduğu ve böylece kolonda asidik bir ortam sağlayarak patojenlerin büyümesini baskıladığı gösterilmiştir (Silva vd., 2019).

Demir ve çinko açısından zengin gıdaların kullanımı, demir ve çinko eksikliklerini azaltabilir. Silva P. ve arkadaşları tarafından yapılan çalışmada psödotahıllardan Chia (*Salvia hispanica L.)* özütünün in vivo olarak etkileri incelenmiş *Lactobacillus* ($p < 0.05$), *Bifidobacterium* ($p < 0.05$), *E. Coli* ($p < 0.05$) ve *Clostridium* ($p < 0.05$) miktarının arttığı gözlemlenmiştir. Diyet lifi tüketimine bağlı olarak *Lactobacillus* ve *Bifidobacterium*daki artışın, doğrudan veya dolaylı olarak demir ve çinkonun biyoyararlanımının artmasına daha fazla katkıda bulunmaktadır. Bu bakteri cinsleri kısa zincirli yağ asitleri üretir (SCFA'lar), bağırsak pH'ını düşüren ve bu nedenle, mineral (Fe ve Zn olarak) çözünürlüğünü ve dolayısıyla emilimini artırmaktadır. *Bifidobacterium* ve *Lactobacillus*, 1,2-glikosidaz aktiviteleri nedeniyle sindirilemeyen lifleri (prebiyotikler) parçalayabilir ve bu da daha fazla SCFA üretimine yol açar, bu da demir ve çinko emiliminde artış sağlamaktadır (Silva vd., 2019). Psödotahıllardan Chia üzerine yapılan bu araştırma gösteriyor ki bağırsak mikrobiyotası için önemli etkilere sahiptir. Ancak diğer psödotahıllar ile ilgili de kapsamlı araştırmaların yapılması gerekmektedir.

Sonuç

Psödotahıllarla ilgili yapılan in vivo çalışmalar göstermiştir ki bağırsak sağlığı, mikrobiyotası ve mineral emilimi açısından olumlu etkileri olmuştur. Çölyak hastası bireyler için glutensiz diyetlere dahil edilerek gıda endüstrisi tarafından ticarileştirilmesi besin ögesi eksikliğini azaltıp psödotahılların yaygınlaştırılmasına katkı sağlayabilir. Çimlendirilen psödotahılların ise antibesin maddelerinin çimlenme ile azaldığı, özellikle fitattaki azalma ile demir emiliminin arttığı, antioksidan aktivitenin, fenolik bileşenlerin arttığı, bazı yararlı yağ asitleri seviyelerinin de iyileştirildiği görülmüştür. Psödotahıllar uygun bir diyet bileşeni olabileceğinden, uzun süreli beslenme denemelerinde ayrıca çimlendirilerek diyetle alımında değerlendirmeyi amaçlayan çalışmalar bütün psödotahıl grubu için yapılmalıdır. Psödotahılların ve çimlendirilerek tüketimlerinin sağlık üzerindeki etkilerinin daha iyi anlaşılabilmesi için daha fazla klinik araştırmaya gereksinim duyulmaktadır.

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Cover crop biomass and organic manure applications for improved soil physico-chemical properties and tomato yield in a continuous-cropped arable land.

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Abstract

The growing global population and limited land resources have made farmers to rely heavily on continuous cropping, which in turn has negatively impacted soil quality and crop productivity. This study, conducted at location is southwest Nigeria, aimed to restore a continuous-cropped arable land. The study assessed the effectiveness of cover crop biomass and organic manure application on soil physical quality and tomato yield through six treatments in two experiments involving groundnut planting and tomato cultivation. The treatments consisted of piggery manure and groundnut residues (PG+G); poultry manure and groundnut residues (PM+G); groundnut residues only (G only); poultry manure only (PM only); piggery manure only (PM only) and control (no manure). Disturbed and undisturbed soil samples were collected, before the experiment and after the harvest of both groundnut and tomato, from the soil depth 0-40 cm, at 10 cm increments. The results showed that organic amendments significantly ($p < 0.05$) increased soil organic matter by 11-38 % in the 0-10 cm surface layer and 15-36 % in the 10-20 cm subsurface layer while it reduced in the control. The pH increased, soil bulk density decreased by 14-27% (0-10 cm) and 3-27% (10-20 cm), soil water content increased by 12-118% (0-10 cm) and 4-30% (10-20 cm) while the soil saturated hydraulic conductivity improved by 17-218% (0-10 cm). Poultry manure gave the highest tomato yield components: ≈ 224 fruits, ≈ 45 mm fruit diameter, and 15.8 ton/ha yield, all significantly ($p < 0.05$) better than the control and other treatments. These findings showed that cover crops biomass cum organic manure could restore the soil physical quality of continuous-cropped arable lands and significantly optimize crop yield.

Key Words: *Continuous cropping; Cover crop biomass; Organic manure; Soil physicochemical properties; Crop performance*

Introduction

Continuous cropping involved cultivating the same crop variety and closely related ones in the same field for an extended period of time (Tan et al., 2021). Due to increase in population and shortage of land resource to meet food demands, adoption of continuous cropping has gained popularity. For instance, at the end of 2013, China had 1.3 million hectares of arable land, 95% of which was under continuous cropping (Kassam et al., 2014). Continuous cropping practices can have a negative impact on crop productivity and quality, decrease soil water holding capacity, and deteriorate soil hydraulic and physicochemical qualities. Previous researches have shown that continuous cropping could cause a series of issues with the soil, including deterioration of the soil's physicochemical qualities, soil enzyme activity decrease, accumulation of auto-toxic substances, microbial community changes and has alteration in soil physicochemical properties, particularly pH and soil nutrients (Ashworth et al., 2020; Chen et al., 2022; Guo et al., 2022, Yu et al., 2023). According to Mahal et al. (2019) and Majhi et al. (2021), continuous cropping reduces soil nutrients, which is a result of crop absorption and repressed C and N mineralization. This limits material transformation cycling and even affects soil nutrients.
Because human-caused land depletion is not avoidable, the need for land restoration through soil conservation techniques is critical to controlling and sustaining agricultural land. Among the most important soil conservation/land management techniques are the application of organic manure to the soil and growing cover crops (Ntamwira et al., 2023). Cover crop plays an important role in improving soil quality by increasing soil organic matter levels over time with the addition of cover crop biomass (Sainju et al., 2021; Wulanningtyas et al., 2021). The objective of the study therefore was to evaluate the efficacy of cover crop biomass and organic manure applications for improved soil physico-chemical properties and tomato yield in a continuous-cropped arable land in southwest Nigeria.

Materials and Methods

Study site

The study was carried out on the Teaching and Research Farm, Ekiti State University, Ado Ekiti, Southwest Nigeria, located on an elevation of 434 m above sea level, with coordinates ranging from 4°45' to 5°45' E longitude and 7°15' to 8°5' N latitude. The region exhibits a humid tropical climate characterized by a moderate mean annual rainfall (≈ 1,667 mm) and clear distinctions between dry and wet seasons. The temperature remains relatively constant throughout the year, with minimal fluctuation from the average range of 27 °C to 28 °C. The soil in the study site was classified as Typical Kandiudalf (Soil Survey Staff, 2014), with a top sandy-loam to subsoil clay texture (Fasina et al., 2005). The study site has been under continuous cultivation of arable crops for over 10 years with less than six months fallow period before the commencement of this study.

Description of the experiment

There were two experiments; the first experiment involved the imposition of organic manure and planting of groundnut for biomass generation and soil evaluation. The second experiment involved further addition of poultry and piggery manure, incorporation of groundnut biomass and, soil evaluation and tomato performance analysis.

Experimental design, treatments and field layout

The study employed a RCBD (randomized complete block design) of six treatments in three replicates. The treatments consisted of groundnut + piggery manure; groundnut + poultry manure; groundnut only; poultry manure only; piggery manure only and no manure at all as the control. There are three blocks, and in each block, plots measuring 2.5 m x 3 m were laid out as shown in Figure 1 below.

Soil sampling

A mini profile, about 40 cm deep, was dug at the center of each experimental site for soil sampling. Undisturbed soil samples, in three replicates, were collected from soil layers 0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm layers using core samplers, 40 mm high and 57 mm diameter. Disturbed soil samples were also collected from same soil layers. The samples were transported to the laboratory for routine analysis of soil physical and chemical properties. In the laboratory, the disturbed soil samples were air-dried, crushed and sieved to remove materials larger than 2 mm with the aid of 2-mm sieve while the undisturbed samples were trimmed to remove excess soil and oven dried. The samples for soil organic carbon and total nitrogen determination were grounded to pass through a 0.5 mm sieve. The samples were kept in a cool place for further analysis for the soil properties.

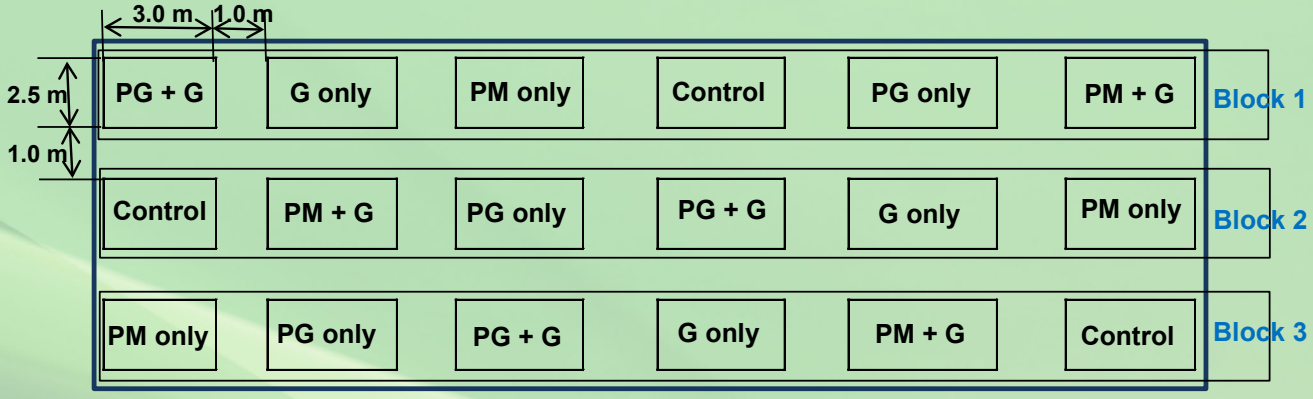


Figure 1: Field layout of the experiment
PG+G: piggery manure and groundnut; G only: groundnut; PM only: poultry manure; PG only: piggery manure; PM+G: poultry manure and groundnut

Laboratory analysis

Soil textural analysis was done using the pipette method (Suzuki et al., 2015), soil particle density was determined using the volumetric flask method (Danielson and Sutherland, 1986) while soil bulk density was evaluated following the methodology described by Blake and Hartge (1986).
Bulk density values were calculated using the following equation:

$$BD = \frac{DM}{V}$$

Where BD is the bulk density (g cm^{-3}), DM is the dry mass (g) of the soil sample, and V is the volume of core sampler (cm^3).

Soil total porosity was obtained from the relation between soil bulk density and particle density (Danielson and Sutherland, 1986). Soil hydraulic conductivity (Ksat, cm h^{-1}) was determined using the constant-head permeameter following the methodology described in EMBRAPA (2011):

$$Ksat = \frac{QL}{A\Delta Ht}$$

Where Q is the volume of water that percolated the soil, cm^3; L is the length of the soil column, cm; A is the cross-sectional area of the core sampler, cm^2; ΔH is the hydraulic head, cm; t is the time of flow in h.

Soil pH was determined in a 1:2 soil water suspension using the digital electrode pH meter, calibrated using buffer solution (Thomas, 1996). Organic matter was quantified using wet oxidation method (Walkley and Black, 1934). A correction factor of 0.39 was used to account for the incomplete combustion of organic carbon. The percent carbon content (OC) of the soil samples was then calculated using the following formula (van Reewijk, 2002).

$$OC, \% = \frac{(ml\ Fe^{2+}\ blank) - (ml\ Fe^{2+}\ soil)x\ Normality\ of\ Fe^{2+}}{Weight\ of\ soil\ in\ g}$$

Tomato yield and yield components

The yield components, including the number of fruits, individual fruit weight (measured in g) were measured and overall fruit yield (metric tons per hectare) was evaluated. Fruit diameter was determined at harvest using a digital vernier caliper, while fruit weight was measured with a precise digital weighing scale during each harvest. The number of fruits was recorded at every harvest session. Fruit yield was calculated by summing all harvested fruits within an experimental unit during the harvest period and was then converted into tons per hectare. The average total yield per hectare was computed by combining both marketable and unmarketable fruit yield, expressed in tons.

Data Analysis

Data collected were subjected to one-way analysis of variance (ANOVA) and means were separated using Duncan Multiple Range Test (DMRT) at 5% level of significance. Dunnet's test was used to compare the control with other treatments. All statistics were done in SPSS software (SPSS, 2011).

Results

Table 1 presents the physicochemical parameters of the site prior to the commencement of the experiment. The site's initial soil results showed increasing bulk density (1.60–1.76 g/cm³) with depth, exceeding optimal levels for plant growth and indicating compaction. The soil is predominantly sandy which showed poor water and nutrient retention. Saturated hydraulic conductivity (12.8–23.5 cm/h) was highest in the top layer, indicating good infiltration, but field capacity and available water were lowest at the surface (0–10 cm), limiting plant moisture access. Organic matter content was low (1.01–1.86%), below the USDA's 3% standard for healthy soil, and decreased with depth. Soil pH ranged from 5.3 to 6.9 which is suitable for most crops. Total nitrogen was low (0.09–0.11%), indicating a need for nitrogen fertilizer application to support plant growth. The available Phosphorus levels (15.7–16.6 mg/kg) was fairly consistent across soil depths, while exchangeable cations (Na, K, Mg, Ca) and acidity were low. Overall, the soil indicate some degree of compaction, low levels of nitrogen and organic matter content requiring improvements for optimal crop productivity.

Table 2 present the physicochemical properties of the soil after groundnut termination. Soil pH increased at the 0–10 cm depth across all treatments compared to pre-experiment data, with minimal variation among treatments and depths. Organic matter (OM) in the surface layer increased by 13–213% due to groundnut cover and organic manure, highest in Poultry Manure (PM) only and lowest in the control. OM generally declined with depth, except in the G only treatment. Surface OM followed the order: PM only > PG+G > PM+G > PG only > G only > Control, a trend also observed in subsurface layers. Bulk density (BD) at 0–10 cm decreased by 7–13% in all treatments except PG only, with PG only and control having the highest BD. Compared to pre-experiment values, surface BD ranked: PG only = Control > G only > PM only > PM+G > PG+G. Subsurface BD increased inconsistently across treatments. Saturated hydraulic conductivity (Ksat) increased by 9–476%, peaking in the PM+G treatment, and declined with depth. Soil water content (SWC) increased by 4–63% at the surface, highest in PM+G and PG+G, and lowest in G only.

For the 0-10 cm surface layer, the control had the highest pH value and showed a significant difference ($p < 0.05$) when compared to other treatments and increased in the order of Cont > PM only > G only > PG only > PM+G = PG+G. For the subsurface layers, there was no significant difference ($p > 0.05$) in pH due to the organic amendments (Figure 4.2a). In contrast, notable variations in soil organic matter content were observed across the different treatments and the two soil layers evaluated.

Apart from control, applying various soil amendments led to a statistically significant ($p < 0.05$) rise in soil organic matter (SOM) in both soil layers with treatment PG+G and Control having the highest and lowest SOM, respectively in both soil layers. The SOM was in the order of PG+G > G only = PM only > PG only > PM+G > Control.

Table 1. Measured some soil physical, hydraulic and chemical properties of the experimental site before the experiment.

Soil chemical properties									
Soil depth	pH_{H2O}	OM	TN	A.P	Na	K	Mg	Ca	EA
cm	-	%	g/kg	mg/kg	----------cmol/kg----------				-
0-10	5.3	1.86	0.11	15.7	0.09	0.79	1.15	3.25	1.35
10-20	6.9	1.55	0.09	16.6	0.06	0.43	1.00	2.75	0.83
20-30	6.5	1.16	0.10	13.4	0.09	0.48	0.90	2.80	0.83
30-40	6.4	1.01	0.09	11.1	0.09	0.54	0.85	2.65	0.88
Limit	6.0-7.5*	3-5**							

Soil physical and hydraulic properties							
Soil depth	BD	Ksat	SWC	Sand	Clay	Silt	Texture
cm	g/cm^3	cm h^{-1}	g/g	----------%----------			
0-10	1.60	23.5	0.104	78.6	10.9	10.5	SL
10-20	1.68	14.2	0.103	76.9	10.4	12.8	SL
20-30	1.74	16.4	0.126	74.4	12.3	13.4	SL
30-40	1.76	12.8	0.147	67.7	23.6	8.7	SCL
Limit	0.9-1.2**	1.8-18**	>0.200**	-	-	-	-

*FAO (2021); **Reynolds et al. (2015); OM: organic matter; TN: total nitrogen: A.P: available phosphorus; Na: sodium; K: potassium; Mg: magnesium; Ca: calcium; EA: exchangeable acidity; BD: bulk density; Ksat: saturated hydraulic conductivity; SWC: soil water content; SL: sandy loam; SCL: sandy clay loam

Table 2: Measured physical and hydraulic properties of the experimental site after termination of groundnut.

	PG+G	Cont	PM only	G only	PM+G	PG only
Soil depth, cm	pH					
0-10	6.8	6.8	6.9	6.9	6.9	6.8
10-20	6.8	6.7	6.9	6.9	6.9	6.9
20-30	6.8	6.8	6.8	6.8	6.9	6.9
30-40	6.8	6.8	6.8	6.9	6.9	6.9
	OM, %					
0-10	3.9ab	1.6c	5.0a	1.8c	2.9b	2.4bc
10-20	2.4	1.5	3.4	2.4	2.9	2.5
20-30	2.0	1.4	2.9	1.8	2.7	2.2
30-40	1.9	1.5	2.2	1.6	2.7	1.2
	Bulk Density, g cm^{-3}					
0-10	1.3	1.5	1.3	1.4	1.3	1.5
10-20	1.4	1.6	1.6	1.5	1.6	1.6
20-30	1.4	1.6	1.6	1.6	1.6	1.7
30-40	1.7	1.6	1.7	1.6	1.7	1.9
	Ksat, cm h^{-1}					
0-10	144.7b	39.7e	60.8d	43.4e	228.5a	84.5c
10-20	36.7	12.4	43.9	18.6	127.9	69.7
20-30	5.3	17.6	68.7	59.3	189.6	96.6
30-40	2.8	33.5	49.0	66.6	95.1	33.1
	SWC, %					
0-10	23.6a	14.5b	15.1b	14.4b	23.6a	12.9b
10-20	16.5	12.7	12.6	13.9	12.8	11.8
20-30	10.7	11.3	10.2	11.0	11.3	11.5
30-40	18.0	12.5	12.3	10.6	14.2	12.7

PG+G: piggery manure and groundnut; G only: groundnut; PM only: poultry manure; PG only: piggery manure; PM+G: poultry manure and groundnut, OM: organic matter; BD: bulk density; Ksat: saturated hydraulic conductivity; SWC: soil water content

The soil BD, aggregate stability index (ASI), Ksat, and SWC of the different soil layers after tomato harvest are presented in figüre 3. The BD differed significantly ($p < 0.05$) in all the soil layers as a result of groundnut cover crop biomass and organic manure addition. At the 0-10 cm surface layer, BD was highest in the treatment G only and lowest in the treatment PG+G while at other layers, the Control had the highest BD. For the 10 - 20 and 20 - 30 cm subsurface layers, the Control had the significantly ($p < 0.05$) highest BD compared to other treatments. For the 30-40 cm layer, the BD was significantly ($p < 0.05$) higher from the Control, G only and PM than other treatments. The ASI was significantly influenced ($p < 0.05$) by groundnut cover crop biomass and organic manure addition only at the 0 - 10 and 10 - 20 cm soil layers. In the 0 - 10 cm surface layer, the Control had the highest ASI but this did not differ ($p > 0.05$) from those of treatments PM+G and PG+G. At the 10 - 20 cm, the Control and treatments G only and PG+G had higher ($p < 0.05$) ASI compared to others.

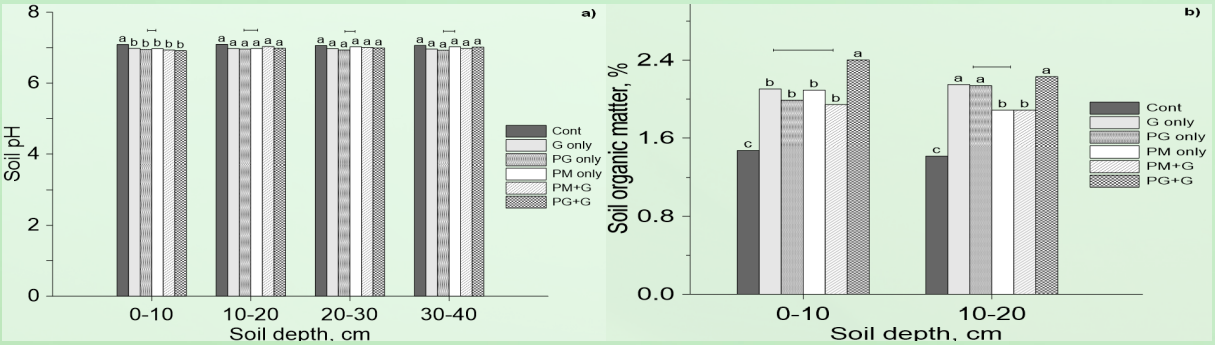


Figure 2. a) pH and b) matter content of the different soil layers after harvest of tomato.

PG+G: Piggery manure and groundnut biomass; PM: Poultry manure only; G: groundnut only; PM+G: Piggery manure and groundnut biomass; PG: Piggery manure only; Cont: Control; The horizontal bars are the standard error of the mean; Vertical bars with different letters differed significantly at 5% level of probability by Duncan Multiple Range test.

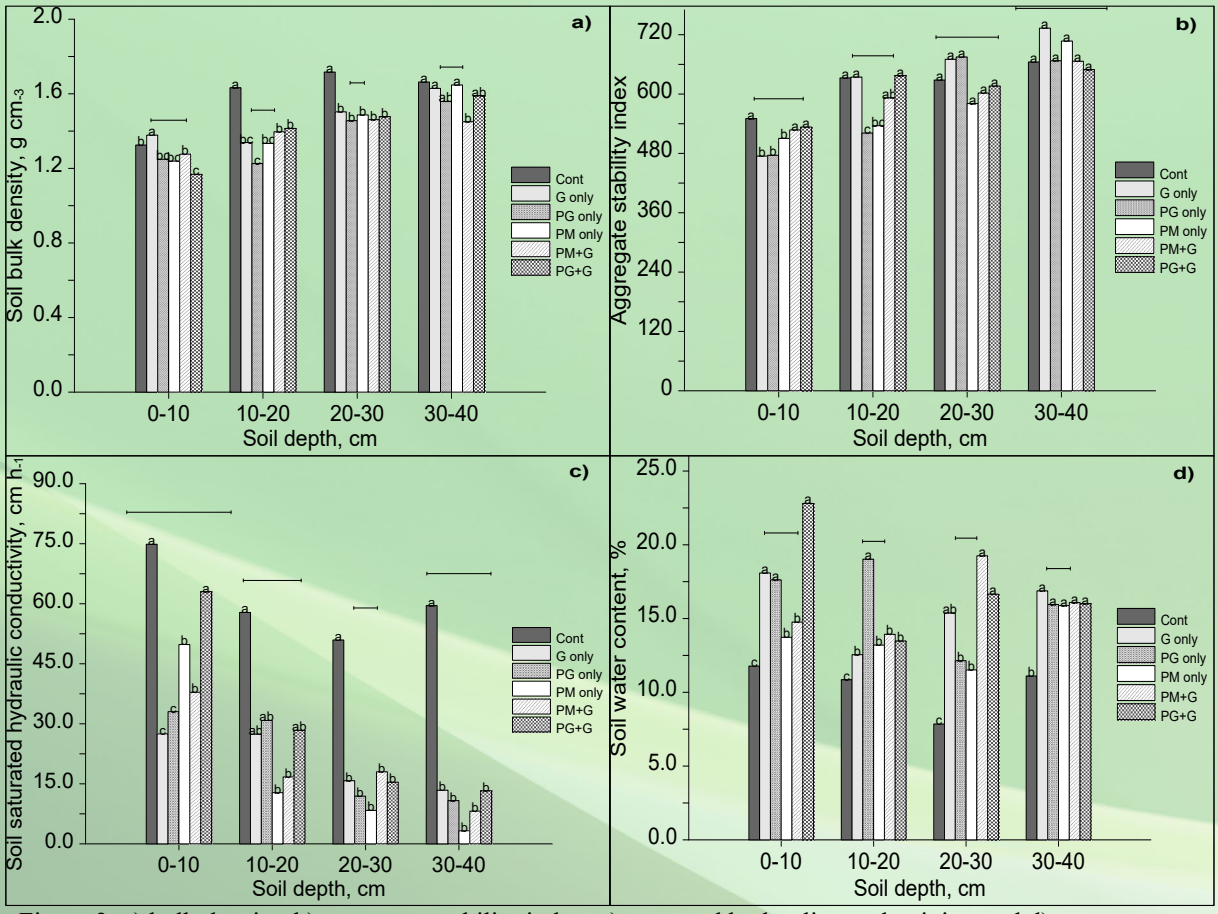


Figure 3. a) bulk density, b) aggregate stability index, c) saturated hydraulic conductivity, and d) water content of the different soil layers after harvest of tomato.

PG+G: Piggery manure and groundnut biomass; PM: Poultry manure only; G: groundnut only; PM+G: Piggery manure and groundnut biomass; PG: Piggery manure only; Cont: Control; The horizontal bars are the standard error of the mean Vertical bars with different letters differed significantly at 5% level of probability by Duncan Multiple Range test.

Table 3 shows the data on the yield as well as the yield components of the tomato crop under different soil amendments. The use of soil amendments was observed to have a significant ($p < 0.05$) effect on both the quantity of fruit produced and the overall yield. The plot treated with a combination of PG+G resulted in the maximum fruit yield, whereas the plots treated with G only and the control had the minimum fruit yield. Nevertheless, except from the control and the G only, no statistically significant differences ($p > 0.05$) were seen among the remaining treatments. Furthermore, it was observed that the PM treatment had the biggest fruit diameter whereas the G treatment displayed the smallest fruit diameter. In addition to the PG only and PG+G treatments, statistically significant differences ($p < 0.05$) were seen across the remaining treatment groups. The results of the study revealed a statistically significant ($p< 0.05$) impact of soil amendments on tomato yield. The plots treated with a combination of PG+G, PM+G, PM, and PG gave similar yield, which were considerably distinct ($p < 0.05$) from those of the treatment with G only and control. When compared to the control, the poultry treatment exhibited the most notable outcomes in terms of tomato fruit quantity (about 224 fruits), fruit diameter (approximately 45 mm), and yield (15.8 ton/ha).

Table 3. Yield and yield components of the tomato crop under different soil amendments.

Treatments	Number of Fruits	Fruit Diameter, cm	Yield, ton\ha
Control	170.3b	43.1abc	12.2b
G only	159.0b	40.9c	10.2c
PG only	210.0a	43.7ab	13.8a
PM only	223.3a	44.8a	15.8a
PM+G	207.0a	43.9ab	14.1a
PG+G	230.3a	42.3bc	15.0a
SEM	45.49	0.73	3.45

PG+G: Piggery manure and groundnut biomass; PM: Poultry manure only; G: groundnut only; PM+G: Piggery manure and groundnut biomass; PG: Piggery manure only; Cont: Control
SEM: standard error of the mean
Columns with different letters differed significantly at 5% level of probability by Duncan Multiple Range Test (DMRT)

Discussion

Initial soil conditions

The pH of the 0-10 cm surface layer was outside the range (below the lower limit) while those of the subsurface layers were within the range considered acceptable for most plants according to FAO standard operating procedure for soil pH determination (FAO, 2021). The organic matter content is generally low and decreased with soil depth. Fertile soil is soil that has been supplemented with nutrients. A fertile soil may be inherent or natural, and manures or artificial fertilizers can be used to get it (Ansa et al., 2022). Physical, chemical, or biological elements may have impacts on soil fertility, which in turn may have effects on plant growth. Plants cannot absorb nutrients like nitrogen, phosphorus, sulfur, and carbon as they are; instead, they must be transformed by microorganisms through nutrient cycling into their normal forms. The soil bulk density (BD) is high and increased with soil depth. The optimal BD for most soil textures should be in the range of $0.9 \leq BD \leq 1.20$ g cm^{-3} (Reynolds et al., 2015). For this site, the BD was well above the range, indicating denser soil. Furthermore, the higher BD observed 20-30 cm and 30-40 cm subsurface layers are close to the range 1.75–1.85 g cm^{-3} considered restrictive soil condition which could impair water and air movement, root morphology and crop development (Reichert et al., 2018). The 0-10 cm surface layer had Ksat above the 18 cm h^{-1} designated as the upper optimal limit for humid climates, indicating susceptibility to doughtiness and nutrient leaching while the subsurface layers had Ksat within the optimal range ($1.8 \leq Ksat \leq 18.0$ cm h^{-1}) for crop essential water and drainage of excess water. The 0-10 cm and 10-20 cm layers had SWC below ideal for adequate root growth and drought resilience (Reynolds et al., 2015) while the higher SWC in the subsurface layers is attributed to the higher clay content (Table 1). The total nitrogen values were between 0.09 and 0.11 g kg^{-1}, while the available phosphorus had values between 11.1 and 16.6 mg kg^{-1}. The exchangeable bases (Na, Mg, K and Ca) and exchangeable acidity were highest in the 0-10 cm surface layer.

Soil conditions after the first experiment (planting of groundnut cum addition of organic manure)

The soil pH was at par across different treatments and depths, ranging from 6.7 to 6.9. This stability suggests that the treatments applied do not significantly impact the soil acidity, which is essential for nutrient availability and microbial activity (Brady and Weil, 2008). The soil organic matter content of the 0-10 cm surface layer increased between about 13 and 213% due to groundnut cover crop and organic manure addition compared to the control, with the PM only treatment having the highest organic matter content, indicating its potential in improving soil fertility (Lal, 2024).

For the 0-10 cm surface layer, except the PG treatment, the BD decreased between 7 and 13% due to groundnut cover crop and organic manure application compared to the control, with the highest observed in the treatment PG

only and control. The lower BD values in PG+G, PM, PM+G suggest improved soil structure. Compared to the pre-experiment soil conditions, the BD had decreased on the surface soil in the order PG only = Control > G only > PM only > PM+G >PG+G. For the subsurface layers, the BD increased but without any discernible trend among the treatments. Ksat of the 0-10 cm surface layer increased between 9 and 476% due to groundnut cover crop and organic manure application, with the PM+G treatment having an exceptionally high Ksat compared to other treatments. The higher Ksat observed in the plots with groundnut cover crop and organic manure indicates increased drainage these treatments (Saxton and Rawls, 2006). Similarly, the SWC of the 0-10 cm surface layer increased between 4 and 63% due to groundnut cover crop and organic manure application compared to the control. The higher SWC in the treatments suggests better water retention (Vereecken et al., 2010).

Soil conditions after harvest of tomato

At the harvest of tomato, the soil pH of the 0-10 cm surface layer had increased between about 31% in all treatments including the Control compared to pre-experiment data. For the subsurface layers, groundnut cover crop biomass and organic manure addition did not influence ($p > 0.05$) the soil pH. While the pH was almost at par in the 10-20 cm soil layer, it slightly increased by about 8% in the 20-30 and 30-40 cm deeper layers at harvest of tomato.

Soil organic matter content was significantly ($p < 0.05$) affected by groundnut cover crop biomass and organic manure addition in both soil layers, with the control having the lowest values. Compare to pre-experiment condition, SOM had increased between 4.4 and 29.2% with the trend PG+G > G only > PM only > PG only > PM+G while it decreased by about 21% in the control at the 0-10 cm surface layer. Similar trend was observed for the 10-20 cm subsurface layer. Cover crops have also been reported to increase soil organic matter by 7-12% compared to no cover crop management (Hu et al., 2023; Peng et al.,2023) and this can lead to improved soil aggregate formation and increased water infiltration (Arel et al., 2022, Shen et al., 2021) Therefore, it can be said that organic manures are beneficial sources of nutrients in addition to improving the physical environment of the soil. Similar results were showed (Dhaliwal et al., 2023, Goldan et al., 2023, Köninger et al., 2021). The highest organic carbon content was noticed with the application of piggery manure and groundnut (2.4%). Nevertheless, application of nutrients in organic form would improve the crop growth and leaves behind several residues including crop root. Perhaps, slow mineralization could lead to organic carbon accumulation in soil.

The soil BD, aggregate stability index (ASI), Ksat and SWC of the different soil layers after tomato harvest are presented in figure 3. The BD differed significantly ($p < 0.05$) in all the soil layers as a result of groundnut cover crop biomass and organic manure addition. For the 0-10 cm surface layer, BD was highest in the treatment G only and lowest in the treatment PG+G. Compared to the pre-experiment soil conditions, the BD had decreased between 13.8 and 27.0% even in the control in the order PG+G > PM only > PG only > PM+G > Control > G only. For the subsurface layers, the BD also decreased but without any discernible trend among the treatments (Figure 3a). The ASI was significantly influenced ($p < 0.05$) by groundnut cover crop biomass and organic manure addition only at the 0-10 and 10-20 cm layers, with the Control having the highest ASI but this did not differ from those of treatments G only, PM+G and PG+G.

In addition, the ASI had decreased by 7.4% in treatment PG+G and 17.6% in treatment G only compared to the about 4% reduction in the Control (Figure 3b).

Soil Ksat was significantly highest ($p > 0.05$) in the Control compared to other treatments for all the soil layers evaluated, with the treatment G only having the lowest Ksat at the 0-10 cm surface layer. For other layers, the trend observed in the surface layer was not followed. Compared to the pre-experiment data, Ksat increased between 17% (treatment G only) and 218% (Control) in the 0-10 cm surface layer. For the subsurface layers, the Ksat either increased or decreased (Figure 3c).

At harvest of tomato, the SWC of the 0-10 cm surface layer was significantly lowest ($p < 0.05$) in the Control and highest in the treatment PG+G compared to other treatments. For subsurface layers, the Control also had the significantly lowest SWC while there was no discernible trend among the treatments. The SWC had also increased between 31.6% (PM only) and 118.6% (PG+G) compared to the 12.9% increase observed in the Control (Figure 3d).

Tomato yield and yield components

Except for the treatment G only, the number of fruits was higher between 21 and 35% for the soil amendment treatments than the control, with the highest increase obtained from the treatment PG+G. For the fruit diameter, the treatments PG only, PM only and PM+G treatments had tomato fruits bigger than the control by 1.4, 3.9 and 1.9%, respectively. The highest tomato yield was observed in treatment with PM only but did not statistically differ from those of the treatments PM+G, PG+G, and PG only while the treatment G only had the lowest yield. Furthermore, the treatments PG only, PM only, PM+G and PG+G had yield higher than the control by 13, 30, 16 and 23%, respectively. The notable enhancement in tomato yields can be mainly attributed to the stabilization of soil structure. This stabilization has led to a decrease in soil bulk density, an increase in porosity, improved infiltration rates, and enhanced water retention capacity. These beneficial changes in soil physics are the key factors behind the significant boost in tomato production observed in the plots where these amendments were

applied. These findings are consistent with previous studies (Downie et al., 2009; Stewart-Wade, 2020). Previous research highlighted the substantial impact of cover crops and organic amendments on tomato yield when compared to the control (Wang et al., 2018).

Conclusion

The study demonstrated that using cover crops and organic manures significantly enhances soil quality, which in turn leads to increased tomato yield. These organic amendments improved soil physical properties by reducing bulk density and increasing hydraulic water content, water retention, and available water. This ensures better soil water dynamics, supporting plant growth during critical periods. Also, the amendments increased soil pH and raised organic matter content, further contributing to soil fertility and productivity. Overall, organic manure and cover crops positively influenced both growth and yield components of tomato, suggesting that degraded arable land can be restored through sustainable practices. Based on these findings, the study recommends that farmers in Ekiti State adopt soil amendments, particularly poultry and piggery manure, either alone or combined with groundnut, to improve tomato production and promote sustainable agriculture.

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Applications of Mycorrhiza in Plant Development

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Abstract

With the rapid increase in the world population, a significant increase in global food demand is expected. However, due to the threat of future drought and the limited availability of new agricultural land, meeting this demand appears to be possible only through increased productivity in existing cultivation areas. This situation has heightened the need for yield-oriented cultural practices such as expanding irrigation capacity and the widespread use of chemical fertilizers, in addition to conventional breeding efforts. Although the intensive and long-term use of chemical fertilizers contributes to short-term yield increases, it adversely affects soil health by reducing microbial diversity and weakening plant–microorganism interactions. Therefore, within the framework of sustainable agricultural practices, the development of environmentally friendly alternative approaches that can reduce dependency on chemical inputs has become increasingly important. Microbial fertilizers have drawn attention in this context, and among them, mycorrhizal fungi stand out as important bio-inputs that support plant growth. Mycorrhiza is defined as a mutualistic symbiotic relationship between plant roots and soil fungi. Mycorrhizal fungi enhance nutrient uptake efficiency through their extensive hyphal networks, which increase root surface area and facilitate the transport of essential nutrients—particularly phosphorus, as well as zinc, iron, potassium, and nitrogen. Moreover, by strengthening the microbial balance within the mycorrhizosphere, they promote plant growth, suppress pathogenic organisms, and enhance plant tolerance to stress conditions. This review evaluates the morphological, physiological, and microbial effects of mycorrhizal applications on plant development in light of recent findings in the scientific literature.

Key Words: *plant nutrition, fertilization, mycorrhiza, biocontrol, sustainable agriculture*

Bitki Gelişiminde Mikoriza Uygulamaları

Özet

Dünya nüfusundaki hızlı artış ile beraber küresel gıda talebinde önemli ölçüde artış beklenirken özellikle artan kuraklık tehlikesi ve yeni tarım alanlarının sınırlı oluşu gibi sebeplerden dolayı bu talebin karşılanması yalnızca mevcut üretim alanlarında verim artışıyla mümkün gözükmektedir. Bu durum, geleneksel ıslah çalışmalarının yanı sıra sulama olanaklarının artırılması ve kimyasal gübre kullanımının yaygınlaştırılması gibi verim odaklı kültürel uygulamalara olan ihtiyacı artırmıştır. Kimyasal gübrelerin yoğun ve uzun süreli kullanımı, kısa vadeli verim artışına katkı sağlarken, toprak mikrobiyal çeşitliliğini azaltmakta ve toprak sağlığına olumsuz etkilerde bulunmaktadır. Bu nedenle, sürdürülebilir tarım uygulamaları kapsamında kimyasal girdilere olan bağımlılığı azaltacak, çevre dostu alternatif yaklaşımların geliştirilmesi özellikle son yıllarda önem bir hedef haline gelmiştir. Bu bağlamda mikrobiyal gübreler dikkat çekerken, bunlar arasında mikoriza mantarları bitki gelişimini destekleyen önemli biyo-girdiler olarak ön plana çıkmaktadır. Mikoriza, bitki kökleri ile toprak mantarları arasında kurulan karşılıklı yarar esasına dayalı bir simbiyotik ilişkidir. Mikorizal mantarlar, kök yüzey alanını artıran hif yapıları sayesinde besin elementlerinin daha etkin alımını sağlamakta; başta fosfor olmak üzere çinko, demir, potasyum ve azot gibi elementlerin taşınımını kolaylaştırmaktadır. Ayrıca mikorizosferdeki mikrobiyal dengeyi güçlendirerek bitkinin büyümesini teşvik etmekte, patojen baskısını azaltmakta ve stres koşullarına karşı tolerans kazandırmaktadır. Bu derlemede, mikoriza uygulamalarının bitki gelişimi üzerindeki morfolojik, fizyolojik ve mikrobiyal etkileri güncel literatür bulguları ışığında değerlendirilmiştir.

Anahtar Kelimeler: *bitki besleme, gübreleme, mikoriza, biyokontrol, sürdürülebilir tarım*

ID: 457

Dünya'da Ve Türkiye'de Patates Üretimi İle Yerli Ve Milli Patates Geliştirme Çalışmaları

Uğur PIRLAK, Necmettin Oğuz DEMİR

Patates Araştırma Enstitüsü Müdürlüğü

Patatesin Önemi

Patates (*Solanum tuberosum* L.) günümüzden 6.000 ile 10.000 yıl önceki bir zaman dilimi içerisinde Peru ve Bolivya sınırları içerisindeki And Dağlarında kültüre alınmaya başlanmıştır. Güney Amerika'nın And dağlarından tüm dünyaya yayılan patates, dünyanın giderek artan açlık sorununa cevap verebilecek önemli bitkilerin başında gelmektedir.

Patates; dünya ve Türkiye için hem taze hem de kendisinden elde edilen yan ürünlerle insan beslenmesinde ve girdi niteliği ile endüstri bakımından önemli bir tarımsal üründür. Yapılan çalışmalara göre, birim alan başına buğdaydan %75 ve pirinçten %58 daha fazla gıda enerjisine sahip olan patates, üretim alanları başına pirinçten %78, buğdaydan %54 daha fazla protein sağlar. Dünya patates üretiminin yarısına yakın kısmı taze olarak değişik formlarda (fırında pişirme, haşlama, kızartma) yemeklik olarak tüketilmektedir. Geri kalan kısmı ise işlenmiş gıda ürünü (dondurulmuş parmak patates ve cips), hayvan yemi, endüstriyel nişasta ve tohumluk olarak kullanılmaktadır. Patatesin nişasta yönünden zengin olan kabukları ve işlendikten sonra kalan diğer değersiz atıklarından sıvılaştırılarak, etanol üretimi amacıyla yararlanılmaktadır.

Doğal kaynakların sürekliliğini sağlamak ve gelecek nesillere gıda güvenliliği yönünden tüketilebilir gıda sağlamak insanlığın en önemli amacı olmalıdır. Patates üretimi bu sorunları çözmede önemli bir araç durumundadır.

Dünya'da ve Türkiye'de Patates Üretimi

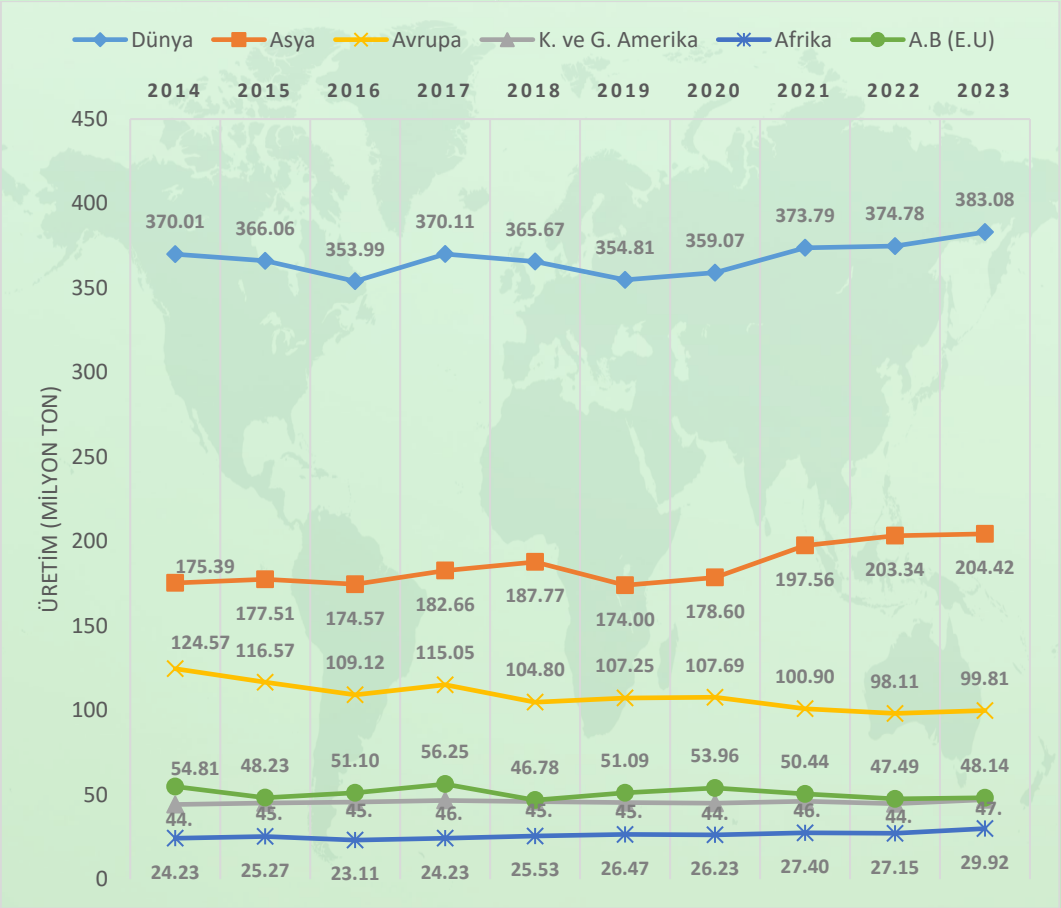
FAO 2023 yılı verilerine göre dünyada toplam 163 ülkede (toplam ülke sayısı 208) yetiştirilen patatesin üretim alanı 16,80 milyon hektar, (*2022; 16,66 milyon ha*) üretim miktarı ise 383,08 milyon ton (*2022; 373,40 Milyon ton*) olmuştur. 2023 yılı itibarıyla en fazla patates üreten on ülke sırasıyla; ***Çin, Hindistan, Ukrayna, ABD, Rusya, Almanya, Bangladeş, Fransa, Pakistan, ve Mısır***'dır. Çin, Hindistan, Ukrayna, ABD ve Rusya ve dünyada sürekli olarak en fazla patates üretiminin yapıldığı ilk beş ülke olurken, bu ülkeler aynı zamanda dünyadaki toplam üretimin de %55,94'ünü gerçekleştirmişlerdir. 2023 yılında Dünya üretiminden Çin %24,39, Hindistan %15,70, Ukrayna %5,58, A.B.D %5,22 ve Rusya %5,06 pay almıştır. Dünya patates üretiminde ülkemiz %1,49'luk pay ile 13. sırada yer almıştır (**Tablo 1.**).

Tablo 1. Dünyada En Çok Patates Üreten İlk On Ülke (FAO, 2023).

Sıra No	Ülke	Üretim Miktarı (Ton)	Dikilen Alan (ha)	Verim (kg /da)
	Dünya	**383.082.607**	**16,80**	**2.280**
1	Çin	93.430.000	4,57	2.045
2	Hindistan	60.142.000	2,33	2.579
3	Ukrayna	21.358.630	1,21	1.765
4	ABD	19.992.090	0,39	5.145
5	Rusya	19.374.441	1,11	1.753
6	Almanya	11.607.300	0,26	4.385
7	Bangladeş	10.431.736	0,46	2.290
8	Fransa	8.606.490	0,20	4.219
9	Pakistan	8.319.767	0,34	2.443
10	Mısır	6.869.330	0,24	2.915
13	**Türkiye**	**5.700.000**	**0,15**	**3.777**

Patates, daha çok Avrupa ve Kuzey Amerika'daki gelişmiş ülkelerde üretilen ve tüketilen bir ürün iken 1990'lı yılların baslarından itibaren özellikle Asya, Afrika ve Latin Amerika'daki az gelişmiş veya gelişmekte olan ülkelerde de patates üretiminin hızla yaygınlaşmaya başlamıştır. Gelişmekte olan ülkelerin toplam üretimi, 1960'lı yılların başında dünya toplam üretiminde az bir paya sahipti ancak günümüzde bu pay gelişmiş ülkelerin üzerine çıkmıştır (**Grafik 1**).

Turkish Science and Technology Publishing (TURSTEP)
www.turstep.com.tr



Grafik 1. 2014-2023 Yılları Arasında Dünya Patates Üretim Miktarları (FAO).

Patates, ülkemiz tarımı içinde en önemli bitki türlerinden biri olup buğday, şeker pancarı, arpa ve domatesten sonra en fazla üretimi yapılan beşinci bitkidir. Ülkemizde ana ürün, turfanda ve ikinci ürün olmak üzere tüm patates üretim sistemleri uygulanmaktadır. Türkiye sahip olduğu agro-ekolojik zenginlik sayesinde patates üretimi açısından oldukça ayrıcalıklı bir konumdadır. Bu nedenle de ülkenin hemen her yöresinde yılın belirli dönemlerinde patates üretimi mümkün olmakta, Nisan ayından başlayarak Aralık ayı sonuna kadar patates hasadı devam etmektedir.

Türkiye'de patates verimi yıllar itibarıyla artış göstermiştir. 2024 yılında patates verimi 3.525,00 kg/da olup 2024 yılı patates veriminin en yüksek olduğu iller sırasıyla Bitlis (4.361 kg/da), Kayseri (4.338 kg/da) ve Adana (4.054 kg/da), olup Türkiye ortalamasının çok üzerindedir (**Tablo 3.**).

Tablo 3. Türkiye'de Yıllara Göre Patates Üretim Verileri (TÜİK).

Yıllar	Dikim Alanı (da)	Alan Artışı (%)	Üretim (Ton)	Üretim Artışı (%)	Verim (kg/da)	Verim Artışı (%)
2017	1.428.835	100	4.800.000	100	3.360,00	100
2018	1.359.373	95,14	4.550.000	94,79	3.348,00	99,64
2019	1.408.967	98,61	4.979.824	103,75	3.538,00	105,30
2020	1.479.935	103,58	5.200.000	108,33	3.514,00	104,58
2021	1.389.175	97,22	5.100.000	106,25	3.682,00	109,58
2022	1.391.716	97,40	5.200.000	108,33	3.739,00	111,28
2023	1.509.269	105,63	5.700.000	118,75	3.777,00	112,41
2024	**1.957.672**	**137,01**	**6.900.000**	**143,75**	**3.525,00**	**104,91**

Niğde, Kayser, Konya ve Afyonkarahisar patates üretiminde önemli dört ilimizdir. Ülke üretiminin yaklaşık %45'ini, ekim alanlarının ise %43'ünü bu üç ilimiz oluşturmaktadır (**Resim 1**).



Resim 1. Türkiye'de Patates Üretimi Yapılan İller ve Üretim Yoğunluğu (TÜİK, 2024).

2024 yılında Türkiye'de 75 ilde patates üretimi gerçekleştirilmiştir. En fazla üretim yapan il Niğde olup 264.830 da alanda 915.734 ton üretim gerçekleşmiştir. Niğde'nin ortalama verimi 3.458,00 kg/da'dır (**Tablo 4.**).

Tablo 2. Yıllara Göre Türkiye'de En Fazla Patates Üretimi Yapılan İller (TÜİK).

2023					2024				
Sıra	**İl**	**Üretim (ton)**	**Dikilen alan (dekar)**	**Verim (kg/da)**	**Sıra**	**İl**	**Üretim (ton)**	**Dikilen alan (dekar)**	**Verim (kg/da)**
1	Niğde	757.480	194.800	3.889	1	Niğde	915.734	264.830	3.458
2	**Kayseri**	**704.041**	**154.094**	**4.569**	**2**	**Kayseri**	**787.842**	**181..602**	**4.338**
3	Afyon	581.850	163.246	3.568	3	Konya	753.717	187849	4.012
4	**İzmir**	**476.543**	**124.040**	**3.842**	**4**	**Afyon**	**688.152**	**205.745**	**3.345**
5	Konya	462.545	108.010	4.282	5	Sivas	560.398	140.108	4.000
6	**Sivas**	**410.377**	**89.862**	**4.567**	**6**	**İzmir**	**478.656**	**130.536**	**3.667**
7	Nevşehir	318.646	83.980	3.794	7	Nevşehir	398.557	115.461	3.452
8	**Aksaray**	**313.453**	**73.899**	**4.242**	**8**	**Adana**	**318.580**	**78.582**	**4.054**
9	Bitlis	273.922	53.180	5.151	9	Bitlis	310.937	71.298	4.361
10	**Adana**	**217.444**	**54.661**	**3.978**	**10**	**Aksaray**	**279.027**	**70.960**	**3.932**

Türkiye'de patates üretimindeki değişim, Avrupa Birliği ülkeleri ile bir paralellik göstermektedir. Patates, bugün ülkenin en önemli tarımsal ürünlerinden biri konumuna gelmiş; üretimi, sanayisi, pazarlaması ve tüketimi ile başlı başına bir sektör halini almıştır.

Ülkemizde kişi başına düşen patates tüketim miktarı yaklaşık (TÜİK 2021- 50,00 kg) **50 kg** civarında olup dünyada kişi başına tüketim ise (FAO 2021- 32,98) **33 kg**'dır. **Ülkemizde patatesin yeterlilik oranı ise 2021 yılı TÜİK verilerine göre %106,10'dir.**

Ülkemizde Patates Çeşidi Geliştirmede Geçmişte Yapılan Çalışmalar

Ülkemizde patates ıslahı ile ilgili çalışmalar, 1951 yılında başlanmış, ülkemizin farklı bölgelerinde yetiştirilmekte olan 60 farklı patates çeşidi (klonu) toplanmış ve bu klonların başlıca özelliklerinin tespit edilmesi amacıyla Ankara ve Adapazarı'nda denemeye alınmıştır. İkinci ayrıntılı çalışma 1961 ve 1962 yıllarında Erzurum'da yürütülmüştür.

Türkiye'de bilimsel anlamda patates çeşit adaptasyon çalışmaları 1950'lerde başlamasına rağmen, çeşit tescil çalışmaları 1970'li yıllarda Ülkesel Patates Projesinin hayata geçirilmesi ile hız kazanmıştır. İlk olarak 1972

yılında Ege Tarımsal Araştırma Enstitüsü tarafından Alpha, Ari ve Sarıkız tescil ettirilmiş; daha sonra 1975 yılında Tohum Islah ve Üretme A.Ş. tarafından Atica, Cosima, Fina ve Frigga çeşitleri; Satüdaş tarafından Baraka, Desiree, Favorita, Jaerla; Ege Tarımsal Araştırma Enstitüsü tarafından Isola ve Resy çeşitleri tescil ettirilmiştir. Daha sonraki yıllarda çeşit tescil çalışmaları özellikle özel sektör girişimleriyle ivme kazanmış ve tescil edilen çeşit sayısı hızla artarak 2024 yılı itibariyle 281'e ulaşmış, üretim izni alan çeşit sayısı ise 48 olmuştur.
Ülkemizde patatesin yaklaşık 175 yıllık bir geçmişi olmasına ve zaman içerisinde patates sektöründe önemli gelişmeler olmasına rağmen, yerli çeşit geliştirme çalışmalarına 2005 yılından sonra hız verilmiştir. Tohumluk firmaları, yerli çeşit ıslahına yatırım yapmak yerine, her yıl temsilciliğini yaptıkları yurt dışı ıslah firmalarından birçok çeşit veya klon getirerek adaptasyon denemelerine almakta ve başarılı olanları tescil ettirmektedirler. Ülkemizde 281 adet tescilli patates çeşidi bulunmakta olup, bunlardan sadece bir tanesi (Nif) Türkiye'de ıslah edilerek tescil ettirilmiştir. Ancak bu çeşit de ticari üretimde hiçbir zaman şans bulamamıştır.

Günümüzde Yapılan Kamu ve Özel Sektör Tarafından Yapılan Çeşit Geliştirme Çalışmaları

Ülkemizde, başta Hollanda olmak üzere Almanya, Fransa, İngiltere, İskoçya, İrlanda ve ABD'de ıslah edilmiş çeşitler kullanılmaktadır. Ülkemize ait yeterli sayıda ve üretim programlarına giren tescilli çeşitlerimizin bulunmaması çok önemli bir problem olarak karşımıza çıkmaktaydı.
Bu sorunun çözümüne yönelik olarak, **1 Kasım 2005- 31 Aralık 2009** tarihlerinde Enstitümüz koordinatörlüğünde TÜBİTAK (1007-KAMAG) destekli, 8 Enstitü (***Niğde Patates Araştırma Enstitüsü Müdürlüğü, Ankara Zirai Mücadele Merkez Araştırma Enstitüsü Müdürlüğü, Bornova Zirai Mücadele Merkez Araştırma Enstitüsü Müdürlüğü, Adana Zirai Mücadele Merkez Araştırma Enstitüsü Müdürlüğü, Erzincan Bahçe Kültürleri Araştırma Enstitüsü Müdürlüğü, Ege Tarımsal Araştırma Enstitüsü Müdürlüğü, Doğu Anadolu Tarımsal Araştırma Enstitüsü Müdürlüğü, Toprak, Gübre ve Su Kaynakları Araştırma Enstitüsü Müdürlüğü***) 3 üniversite (***Mustafa Kemal Üniversitesi, Ege Üniversitesi, Gaziosmanpaşa Üniversitesi***) ve 11 özel sektör firmasının (***Doğa Tohumculuk, Anka Tohumculuk, Ar Tarım, Gömeç Tohumculuk, Sürde Tarım, Tareks, Tezel Tohumculuk, Asgen Tarım, Öztar Tohumculuk, Fritolay Gıda, Kraft Gıda***) katılımı ile **"Ülkesel Patates Tohumluk Üretim Sisteminin Geliştirilmesi"** projesi yürütülmüştür. Proje kapsamında Enstitümüz bünyesinde patates çeşit ıslah programı başlatılmıştır.
Bu program kapsamında patates araştırmaları açısından merkez kuruluş olan Enstitümüzde patates ıslah altyapısı oluşturulmuş ve teknik personel eğitimleri tamamlanmıştır.
Proje çalışmalarımız 2010 yılından itibaren "**Orta Anadolu Patates Islahı Projesi"** ismiyle, Tarım ve Orman Bakanlığı, Tarımsal Araştırmalar ve Politikalar Genel Müdürlüğümüzün destekleri ile sürdürülmektedir. Orta Anadolu Patates Islahı Projesi ile ülkemize uyumlu, yüksek verimli ve hastalıklara dayanıklı yerli çeşitlerin geliştirilmesi, çeşit geliştirme süresinin doku kültürü yöntemi kullanılarak kısaltılması, geliştirilen yeni çeşitlerin ve ülkemizde yaygın olarak üretimi yapılan bazı patates çeşitlerinin temel tohumluklarının doku kültürü ile çoğaltılarak daha kısa sürede çiftçi kullanımına sunulması hedeflenmiştir.
Ülkemize ait yerli çeşitlerin geliştirilmesi kapsamında 2007-2024 yılları arasında ülkemiz açısından bir rekor olan toplam **1.500.000** adet melez patates tohumu elde edilerek **"Patates Genetik Tabanı"** oluşturulmuş, farklı melez kombinasyonlarına ait çeşitli kademelerde (1., 2., 3., 4., 5. generasyon), çok sayıda yerli patates klonları (çeşit adayları) elde edilmiştir. Ülkemize özgü patates çeşit ıslah programları başlatılmış ve sürekliliği sağlanmıştır.
Her geçen yıl üstün verimli çeşitler arasında melezleme çalışmaları yapılmakta farklı jenerasyonlarda (nesillerde) binlerce yeni çeşit adayı üzerinde seleksiyon çalışmaları devam ettirilmektedir. **Her yıl en az iki yerli çeşit tescile sunulacak şekilde patates ıslah çalışmalarımız değişik ıslah projeleri ile devam ettirilmektedir.**
Ülkemizde doku kültürü yöntemi ile patates tohumluk üretimi yokken, "Ülkesel Patates Tohumluk Üretim Sisteminin Geliştirilmesi" projesi ile Niğde Patates Araştırma Enstitüsü, Ege Tarımsal Araştırma Enstitüsü, Doğu Anadolu Tarımsal Araştırma Enstitüsü ve Ege Üniversitesinde tohumluk üretimi yapabilecek doku kültürü laboratuvarları ve seralar 2007 yılında pilot tesisler olarak kurularak işletilmeye başlanmış ve bu alt yapılar kullanılarak çeşit geliştirme çalışmaları hızlanmıştır.
Proje çalışmaları kapsamında seleksiyon çalışmaları sonucunda çeşit adayları (klonlar) içerisinden PA-03-2-16 ve PA-06-1-43 nolu çeşit adaylarımız **07 Ocak 2013** tarihinde ilk yerli ticari patates çeşitlerimiz olarak tescile sunulmuştur. Tescil çalışmaları sonucunda PA-06-1-43 nolu yerli patates çeşidimiz **ONARAN2015** ismiyle ve PA-03-2-16 nolu yerli patates çeşidimiz **FATİH** ismiyle 01 Nisan 2015 tarihinde ilk yerli patates çeşidimiz olarak tescil edilmiştir. 19 Nisan 2016 tarihinde **NAHİTA**, **ÜNLENEN** ve **NAM**, 14.04.2017 tarihinde **ÇAĞLI**, **LEVENTBEY** ve **MURATBEY** ve 12.04.2019 tarihinde **NİĞŞAH** ve **SARUHAN,** 15.04.2025 tarihinde ise **UĞUR** ismiyle toplamda 11 adet yerli patates çeşidi tescil edilmiştir. Ayrıca bu proje TÜBİTAK Araştırma Destek Programları Başkanlığı tarafından hazırlanan **"BAŞARI ÖYKÜLERİ"** kitabında **"Tohumluk Patates İthalatı Yaparken Tohumluk Patates İhracatı Başladı"** başlığıyla 2014 yılında yer almıştır.
Yapılan bu tüm çalışmaların neticesinde; **Türkiye'de ilk defa** geliştirilen yerli ve milli patates tohumluklarının ihale yoluyla satışı gerçekleştirilmiştir.

Tescil edilen 8 adet yerli patates çeşidinden ilk etapta 4 tanesi, enstitüde yapılan ihalede "Tohumluk Üretim ve Pazarlama Hakkı" satışa çıkartılmıştır. **NAHİTA** adlı yerli çeşidin satış hakkı ülkemizde tohumluk patateste en fazla üretim yapan firmalardan bir tanesi olan **AR TARIM TOHUMCULUK SAN ve TİC A.Ş.**' nin olmuştur. Ayrıca NAHİTA adlı çeşidin yurt dışındaki ülkelerde de satılabilmesi için çeşidi alan bu firmayla "Yurtdışı Satış Sözleşmesi" imzalanmıştır.

Devamında **ONARAN2015, ÜNLENEN, NAM, LEVENTBEY ve MURATBEY** çeşitlerinin de "Tohumluk Üretim ve Satış Hakkı" Niğde' de faaliyet gösteren **SELANİK TOHUMCULUK** firmasının olmuştur**.**

En son **NİĞŞAH** ve **SARUHAN** adlı yerli ve milli patates çeşitlerinin "Tohumluk Üretim ve Pazarlama Hakkı" ülkemizde patateste en fazla üretim yapan firmalardan biri olan **HAKAN GIDA ve TOHUMCULUK A.Ş.**'ne ihale edilmiştir. Bu çeşitlerin ileri kademede tohumluk üretimi ve sertifikasyon çalışmaları bu firmalar işbirliğinde devam etmektedir.

2024 yılı Mart Ayı itibariyle özel sektöre devredilen ve sertifikasyon işlemleri tamamlanan **NAHİTA, ONARAN2015** ve **LEVENTBEY** çeşitlerinin çiftçilerimize ve üreticilerimize firma tarafından satışı başlamıştır.

Enstitümüzce yürütülen ıslah çalışmalarında yemeklik, sanayilik ve hastalıklara dayanıklı patates çeşitlerinin geliştirilmesinin yanında farklı kabuk ve et rengine sahip patates çeşitleri de geliştirilmektedir. Geliştirilen renkli, yerli ve milli çeşitlerimiz üzerinde çalışmalarımız devam etmekte olup yeterli tohumluk sayısına ulaşıldığında tescile sunulacaktır.

Geliştirdiğimiz bu renkli çeşitlerimiz üzerinde yapılan teknolojik testler sonucunda çeşitlerimizden iyi kalitede cips elde edilmiştir. Türkiye'de ilk renkli patates cipsleri enstitümüzde geliştirilmiştir. Bu çeşitlerimizin cips piyasasına girmesiyle birlikte ülkemizdeki cips piyasası renklenecektir (örneğin sarı-kırmızı, sarı-lacivert cipsler). Şu an renkli cips yapılabilen 10 genotip enstitümüzce geliştirilmiştir.

2025 yılının Nisan ayında Enstitümüz tarafından ilk defa sanayilik **UĞUR** isimli bir çeşit tescil edilmiştir. Enstitünüzün geliştirmiş olduğu sanayilik çeşit cipslik ve parmak patates yapımına uygun bir çeşit olup yüksek verimli, orta erkenci ve en önemlisi depo dayanıklığı mevcut ithal çeşitlere göre yüksek bir çeşittir.

Enstitümüzün ıslah çalışmaları haricinde Doğru Anadolu Tarımsal Araştırma Enstitüsü, Ege Tarımsal Araştırma Enstitüsü ve Tokat Gaziosmanpaşa Üniversitesi tarafından halihazırda devam eden ve sonuçlanan ıslah çalışmalar kapsamında tescil edilen ve tescile sunulan çeşitler mevcuttur.

Doğu Anadolu Tarımsal Araştırma Enstitüsü Müdürlüğü tarafından yürütülen ıslah çalışmaları kapsamında **CAN, METE, KAAN, ATA 25, KARSU ve CANSU** ismiyle 6 adet yerli ve milli patates çeşidini tescil ettirilmiştir. Yine aynı enstitünün **ARAL** isimli çeşitleri tescil aşamasındadır.

Ege Tarımsal Araştırma Enstitüsü Müdürlüğü tarafından halihazırda tescilli bir çeşidi bulunmayıp "Ege Bölgesi Patates Islahı Projesi" kapsamında ıslah çalışmalarına devam edilmektedir.

Tokat Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü tarafından yürütülen çalışmalar kapsamında **BAŞÇİFTLİK BEYAZI** ve **GÜNGÖR BEY** isimli 2 adet çeşit tescil ettirilmiştir.

Yapılan çalışmaların çıktıları özel sektör tarafından da kullanılmaya başlanmıştır. Birçok tohumculuk firması tohumluk üretimi yapabilecek doku kültürü sistemlerini kurarak doku kültürü ile tohumluk üretim izni almıştır. Bunun sonucunda farklı kademelerde tohumluk üretimi yapmaya başlamışlar ve 2013 yılından itibaren yerli üretim patates tohumluğu ihraç edilmektedir.

En önemli çıktılardan biri de; Özel sektörce yürütülen ıslah çalışmaları ile yerli patates çeşitleri geliştirilmiş, tescile sunulan ve tescil edilen çeşitler olmuştur. Özel sektör tarafından geliştirilerek tescile sunulan çeşit adayları şunlardır;

Doğa Arge Merkezi San. Tic. A.Ş. tarafından toplam 24 adet tescil ettirilen yerli çeşit bulunmakta olup aşağıdaki tabloda bu çeşitlerin isimleri verilmiştir.

Doğa Arge Merkezi San. Tic. A.Ş. (17 Adet)	**BAHAR**	**MADEN**
	İLKMOR	**AYDOS**
	KAYA	**ALTAY**
	ZİRVE	**PETEK**
	DORUK	**KAFKAS1**
	KUTUP	**TESSA**
	VOLKAN	**YAKUT1**
	YEDİVEREN	**DENİZ1**
	YAPRAK	**BULUT**
	YALDIZ	**TURAÇ**
	AYAZ	**SES**
	YANKI	**TAŞ**

Yüksel Tohumculuk Tarım ve Tic. Ltd. Şti. tarafından toplamda 9 adet tescil ettirilen yerli çeşit bulunmakta olup aşağıdaki tabloda bu çeşitlerin isimleri verilmiştir.

Yüksel Tohumculuk Tarım ve Tic. Ltd. Şti. (9 Adet)	**ASYA**
	SOYLU
	CEVHER
	DEMET
	MARATON
	ATABEY
	BOYSAN
	MELANO
	TROVA

İnan Meijer Tohumculuk ve Tic. Ltd. Şti. tarafından ise toplamda 2 adet tescil ettirilen yerli çeşit bulunmaktadır.

İnan Meijer Tohumculuk ve Tic. Ltd. Şti. (2Adet)	**SULTAN ECEM**
	SULTAN NUR

Kamu ve özel sektör tarafından geliştirilen yerli çeşitler hem ülkemizde üretilip çiftçilerimize daha kısa zamanda ulaşacak, hem de dünyaya satışı yapılacaktır. Yerli çeşitlerin devreye girmesiyle birlikte milli ekonomiye büyük katkı sağlanacaktır. Ayrıca yerli çeşitlerimiz patates üreticilerimizin maliyetlerini de önemli ölçüde aşağı düşürecektir. Üreticilerimizin patates tohumluğu ihtiyacı tamamen yerli imkânlarla sağlanacaktır.

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ID: 458

Identification of Novel *TMC1* and *TECTA* Mutations in the Pakistani Population: Insights into the Genetic Basis of Hearing Impairment

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Abstract

Hearing impairment is the 4th most prominent reason for disability worldwide, and according to the WHO report of 2018, the highest prevalence of HI is observed in Europe (8.36%), followed by South Asia (7.37%). The occurrence of significant reciprocal hearing impairment is around 1.6 out of 1000 among individuals of the Pakistani population. This study provides insight into the genetic basis of the hearing loss in the Population of Pakistan. identified by linkage mapping or Exome Sequencing (ES). We found novel mutations in two families, NM_138691.3: c.1259G>A [p. (Cys420Tyr)] and NM_005422.4: c.1247_1248delGG [p. (Gly416Aspfs*24)], in *TMC1* and *TECTA* genes, respectively. Pathogenicity analysis for these novel variants was performed using various insilico tools, which established the deleterious impacts of these variants on the encoded proteins. Variants identified in *TECTA, TMC1* were classified as pathogenic or likely pathogenic. The Clustal W alignment online tool showed the high conservation of the altered amino acid residues by aligning sequences from different species. Further, the effects of alteration in protein were predicted by the 3D modeling and it showed the visible change in structures of proteins for both identified variants. This study would help to expand knowledge and understanding of the genetic spectrum of hearing loss genes in the Pakistani population. Advances in molecular genetics will play a crucial role in the diagnosis and genetic counseling of families affected by hearing loss, ultimately paving the way for progress in personalized medicine and gene therapy.

Key Words: *Hearing loss, TMC1, TECTA, Genetic spectrum , Non Syndromic hearing loss*

ID: 461

Antagonistic Activity of Endophytic Fungi from *Euphorbia rigida* against *Botrytis cinerea* in Tomato

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Abstract

This study was conducted to isolate endophytic fungi from the spurge (*Euphorbia rigida*) plant and to evaluate the *in vitro* biocontrol potential of these isolates against *Botrytis cinerea*. Within the scope of the research, a total of thirty endophytic fungal isolates were obtained from different tissues of *E. rigida*. These isolates were derived from the stem (5), leaf (16), and flower (9) tissues of the plant and were identified based on their macromorphological and micromorphological characteristics. Accordingly, 66.67% of the isolates were determined to belong to *Trichoderma* species. The biocontrol potential of the *Trichoderma* isolates against *B. cinerea*, the causal agent of gray mold disease, was assessed in terms of their antagonistic activity. Dual culture assays were performed on Potato Dextrose Agar (PDA) medium, where the bioagent fungi restricted the mycelial growth of *B. cinerea* by 11 to 35 mm. Among the tested isolates, eight exhibited significant antifungal activity, inhibiting the mycelial growth of the pathogen by 75.5% to 100%. These findings indicate that *E. rigida* harbors fungal endophytes with high biocontrol activity and that these fungi could serve as potential bioagents against *B. cinerea*.

Key Words: *Biological control, Endophytic fungi, Euphorbia rigida, Botrytis cinerea*

Euphorbia rigida'nın Endofitik Funguslarının Domateste *Botrytis cinerea*'ya Karşı Antagonistik Aktivitesi

Özet

Bu çalışma, sütleğen (*Euphorbia rigida*) bitkisinden endofitik fungusları izole etmek ve bu izolatların *Botrytis cinerea*'ya karşı *in vitro* biyokontrol potansiyelini değerlendirmek amacıyla yürütülmüştür. Araştırma kapsamında, sütleğenin farklı dokularından toplam otuz endofit fungus izolatı elde edilmiştir. Bu izolatlar, bitkinin gövde (5), yaprak (16) ve çiçek (9) dokularından izole edilerek, makromorfolojik ve mikromorfolojik özelliklerine göre teşhisleri yapılmıştır. Buna göre, izolatların %66,67'sinin *Trichoderma* sp. türlerine ait olduğu belirlenmiştir. *Trichoderma* izolatlarının, gri küf hastalığı etmeni *Botrytis cinerea*'ya karşı biyokontrol potansiyelleri, antagonistik aktiviteleri bakımından değerlendirilmiştir. Dual kültür testlerinde Patates Dekstroz Agar (PDA) ortamı kullanılmış olup biyoajan funguslar *B. cinerea*'nın miselyal gelişimini 11 ile 35 mm arasında sınırlandırmıştır. Test edilen izolatlardan 8 tanesinin belirgin antifungal aktivite sergilediği tespit edilmiştir. Bu izolatlar, patojenin miselyal gelişimini %75,5 ile %100 arasında inhibe etmiştir. Elde edilen bu bulgular, sütleğenin yüksek biyokontrol aktivitesi olan fungal endofit türlere konukçuluk yaptığını ve bu fungusların *B. cinerea*'ya karşı potansiyel birer biyoajan olarak kullanılabileceğini göstermektedir.

Anahtar Kelimeler: *Biyolojik mücadele, Endofitik fungus, Euphorbia rigida, Botrytis cinerea*

ID: 462

Determination of the Presence and Infection Rates of *Bean common mosaic virus* (BCMV), *Bean yellow mosaic virus* (BYMV) and *Bean common mosaic necrosis virus* (BCMNV) in Bean Planting Areas in Karaman Province

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Abstract

In this study, the presence and current status of some virus diseases were investigated in the production areas of Karaman province, which has an important place in terms of bean cultivation in Türkiye. In bean cultivation, many physiological and pathological factors can have negative effects on yield and quality of the crop. Virus diseases are one of the biotic diseases that are problematic in bean cultivation. In particular, some virus diseases can be transmitted by bean seeds and vector insects, which are widely found in nature, making them an important problem in bean cultivation. The investigated viruses were *Bean common mosaic virus* (BCMV), *Bean yellow mosaic virus* (BYMV) and *Bean common mosaic necrosis virus* (BCMNV) belonging to *Potyvirus* genus of *Potyviridae* family. As a result of the surveys conducted in Karaman bean production areas, 140 leaf samples were taken from bean plants in 2023 production season. Sampled bean leaves were exhibited viral disease symptoms such as mosaic, chlorosis, deformations, wilting, and stunting. The presence of the specified viruses in the collected samples was tested by DAS-ELISA method. As a result of the study, 20 of the samples were found to be infected with at least one of the viruses. In other words, 14.29% of the tested plant samples were found to be infected with at least one of these viruses. Of these 20 samples, 11 were infected with BCMV, 4 with BCMNV, 1 with BYMV, 3 with BCMV+BCMNV and 1 with BCMV+BYMV+BCMNV.

Key Words: *BCMV, BCMNV, Bean, BYMV, DAS-ELISA, Karaman*

Fasulye Adi Mozaik Virüsü (*Bean common mosaic virus*, BCMV), Fasulye Sarı Mozaik Virüsü (*Bean yellow mosaic virus*, BYMV) ve Fasulye Adi Mozaik Nekroz Virüsü (*Bean common mosaic necrosis virus*, BCMNV)'nün Karaman İli Fasulye Ekim Alanlarında Varlıklarının ve Bulaşıklık Oranlarının Belirlenmesi

Özet

Bu çalışmada Türkiye fasulye yetiştiriciliği açısından önemli bir yeri olan Karaman ilindeki üretim alanlarında, bazı virüs hastalıklarının varlığı ve mevcut durumları araştırılmıştır. Fasulye yetiştiriciliğinde pekçok fizyolojik ve patolojik etken verim ve kalite üzerinde olumsuz etkilerde bulunabilmektedir. Virüs hastalıkları da fasulye yetiştiriciliğinde sorun olan biyotik kaynaklı hastalık etmenlerinden bir tanesidir. Özellikle bazı virüs hastalıklarının fasulye tohumları ve doğada yaygın olarak bulunan vektör böceklerle taşınabilmeleri fasulye yetiştirciliğinde önemli bir sorun haline gelmelerine sebep olmaktadır. Araştırılan virüs etmenleri *Potyviridae* familyasının *Potyvirus* cinsine ait olan Fasulye adi mozaik virüsü (*Bean common mosaic virus*, BCMV), Fasulye sarı mozaik virüsü (*Bean yellow mosaic virus*, BYMV) ve Fasulye adi mozaik nekroz virüsü (*Bean common mosaic necrosis virus*, BCMNV)'dür. Karaman fasulye üretim alanlarında, 2023 yılı üretim sezonunda yapılan sürveyler sonucunda yapraklarda mozaik, kloroz, şekil bozuklukları ve bitkinin tamamında ise solgunluk, ve bodurluk gibi viral hastalık simptomları sergileyen fasulye bitkilerinden 140 yaprak örneği alınmıştır. Toplanan örneklerde, belirtilen virüslerin varlığı DAS-ELISA yöntemiyle araştırılmıştır. Çalışmanın sonucunda örneklerden 20 tanesinin söz konusu virüslerden en az bir tanesi ile bulaşık olduğu belirlenmiştir. Başka bir ifadeyle, testlenen bitki örneklerinin %14,29'unun bu virüslerden en az bir tanesi ile bulaşık olduğu tespit edilmiştir. Bu 20 örnekten 11 tanesinin BCMV, 4 tanesinin BCMNV, 1 tanesinin BYMV, 3 tanesinin BCMV+BCMNV ve 1 tanesinin BCMV+BYMV+BCMNV ile bulaşık olduğu tespit edilmiştir.

Anahtar Kelimeler: *BCMV, BCMNV, BYMV, DAS-ELISA, Fasulye, Karaman*

ID: 463

Ethiopia's Livestock Production and its Contribution to Food Security

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Abstract

Livestock production plays a fundamental role in ensuring food security and sustaining livelihoods in Ethiopia. This study employs thematic analysis to systematically examine peer-reviewed literature, government reports, and development agency publications to assess how livestock contributes to food security in the Ethiopian context. The analysis identifies four key themes: (1) nutritional contributions through animal-source foods, (2) income generation and economic resilience, (3) integration with crop production systems, and (4) climate change adaptation strategies. Findings reveal that livestock provides 16-20% of total calorie intake and 25-30% of dietary protein for rural households, while serving as a critical asset for risk mitigation during food shortages. However, systemic challenges including feed deficits (estimated at 40-60% of requirements), disease prevalence, and market access limitations constrain full productivity potential. The study concludes with policy recommendations emphasizing the need for integrated livestock-crop systems, improved animal health services, and climate-smart production practices to enhance the sector's contribution to national food security goals.

Keywords: *Livestock production, food security, Ethiopia, thematic analysis, climate adaptation*

ID: 464

Using compost and compost tea as biofertilizers to improve onion growth and yield in the field at Gapring-Lara in the Department of Mayo Kani (Cameroon)

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Abstract

In Cameroon, onion production has grown but poor agricultural practices are challenges to be addressed in order to improve its production. The aim of this study is to assess the fertilizing effects of compost and compost tea on onion growth and production, in order to provide a plausible alternative to synthetic chemical inputs. The study was conducted at the Gapring-Lara experimental site (Cameroon). The experimental set-up used was a randomized complete block consisting of three replications and five treatments including Cow dung compost (Cp), Cow dung compost tea (CpT), Cow dung compost + Cow dung compost tea (Cp+CpT), Negative control (Ctrl) and NPK 20-10-10 (ChF). The results showed that the experimental soils contained high concentrations of phosphorus, potassium, calcium, iron, magnesium and nitrogen after experimentation. Four species of bacteria (*Pseudomonas* sp., *Bacillus cereus*, *Bacillus subtilis* and *Micrococcus* sp.) were determined, with *Pseudomonas* sp. dominating in the compost (69.14%) and compost tea (56.32%). The plots amended with compost had the best average harvest weights, with 248.33±88.08g and 234±77.61g respectively over the two years of the study. Agronomic production was considerably increased by the CpT treatment with 65.48 t/ha in 2018/2019 and by the Cp treatment with 28.14 t/ha in 2019/2020. In view of the results obtained, this study shows the value of using organic matter as a fertilizer in onion cropping systems, in order to increase soil productivity and ensure its sustainable use.

Keywords: *Onion, fertilization, compost, compost tea, Gapring-Lara.*

ID: 466

Sustainable Feed to Reduce the Environmental Impact of Poultry Production

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Abstract

The increasing global demand for poultry products presents significant environmental challenges, particularly concerning resource-intensive feed production. Traditional feed ingredients, such as soybean and maize, contribute to deforestation, water depletion, and greenhouse gas emissions. Additionally, nutrient runoff from poultry waste leads to water contamination and ecosystem degradation. Sustainable feed alternatives, including insect-based proteins offer viable solutions to mitigate these environmental impacts while maintaining nutritional efficiency. The integration of these alternative feed sources reduces dependence on conventional crops, enhances circular economy principles, and promotes waste valorization. Furthermore, utilizing insect meal and single-cell proteins improves feed conversion efficiency and minimizes land and water use, making poultry production more sustainable. The adoption of these feed innovations not only supports environmental conservation efforts but also ensures food security for a rapidly growing population. Transitioning toward sustainable feed practices is essential for aligning poultry production with global sustainability goals, reducing its ecological footprint, and fostering a more resilient agricultural system. This paper highlights the critical role of sustainable feed ingredients in shaping the future of poultry production, emphasizing their necessity in addressing climate change, resource scarcity, and environmental degradation.

Keywords: *Poultry, feed, insects, sustainability, environment.*

1. Introduction

Poultry farming is one of the most important areas in global agriculture, providing billions of people with essential protein in the form of meat and eggs. With the world's population predicted to reach over 10 billion by 2050, the demand for poultry products is projected to soar. By 2028, the sector is predicted to have grown from $360.5 billion in 2023 to $494.55 billion, a spectacular rate of development (World Bank Group, 2013)

This expansion however raises considerable environmental concerns, particularly in the manufacturing of conventional poultry feed. Crops like corn and soy which need a lot of resources to grow make up most of the traditional poultry feed. These feed ingredients' production results in excessive water use, deforestation, and greenhouse gas emissions (Morgan et al., 2025). The environmental impacts of conventional poultry feed extend beyond resource use. Nutrient runoff from feed crop cultivation and poultry waste can lead to water pollution, causing eutrophication in aquatic ecosystems. These challenges highlight the urgent need for sustainable alternatives that can reduce the ecological footprint of poultry production while ensuring food security **(**FAO, 2023a**).**

Sustainable feed ingredients, such as insect-based proteins, algae, and agricultural by-products, offer promising solutions. These alternatives not only have a lower environmental impact but also contribute to a circular economy by utilizing waste streams and reducing dependency on traditional feed crops (Bist et al., 2024).

This article highlights the advantages and prospective applications of sustainable feed components in addressing the environmental issues associated with poultry production.

2. Environmental Challenges in Poultry Production

The production of poultry presents substantial environmental issues even though it is necessary to supply global dietary needs. The environmental effects of poultry farming are not limited to certain regions rather a worldwide effect; Among crucial challenges are greenhouse gas emissions, solid waste management, odor pollution and contamination of water streams are of concern associated with energy use in the the manufacture of concentrate feed, transportation of processed goods and in animal production activities (Castellini et al., 2012).

2.1. Climate Change: Greenhouse Gas Emissions

Air pollutants emissions from animal feeding operations are a significant environmental hazard due to their high potential risk to air quality, human and animal health. Climate change particulate matter (PM) and other gases, such as greenhouse gases and ammonia (NH_3), are the main air emissions (Maheshwari, 2013). Poultry industry must work on lessening its environmental impact, even though its carbon emissions are fewer than those of the beef, pork, or lamb/mutton industries. On average, poultry have a carbon footprint of about 6.0 kg CO_2-equivalent per kilogram of meat (Bist & Chai, 2022). The intensification of feed production, which necessitates energy input for the synthesis of mineral fertilizer and the subsequent use of this fertilizer in the feed production process, indirectly affects emissions of greenhouse gases like carbon dioxide and nitrous oxide. An estimated 18 million tonnes of carbon dioxide are emitted annually, or roughly 44% of the total emissions attributed to the livestock sector, based on the energy use per tonne of nitrogen fertilizer. The (Intergovernmental Panel on Climate Change) emission factor the total nitrogen fertilizer use in the production of feed for poultry production (estimated at 7.2 million tonnes) (Gerber et al. 2006).

Furthermore, a significant source of methane (CH_3) and N_2O emissions is poultry manure. Methane is generated by methanogenic archaea, microorganisms that thrive in oxygen-free (anaerobic) environments. When poultry manure is stored in piles, lagoons, or other confined systems, it creates ideal conditions for these microbes to break down organic matter. This process, known as anaerobic digestion produces methane as a byproduct, a greenhouse gas that has a 28–34 times greater potential to cause global warming over a 100-year period than CO_2. As nitrogen compounds in manure break down, nitrous oxide is generated as well, and it has a 265-fold higher potential to cause global warming than CO_2 (Morgan, 2025).

These emissions add up to the carbon footprint of the poultry business, which makes it a major contributor to global agriculture GHG emissions. In order to meet climate targets and guarantee the sustainability of chicken production, these emissions must be addressed (FAO, 2023b).

2.2. Ecosystems Pollution: Runoff from Poultry Waste and Feed Production

Solid waste is generated at every stage of the chicken production process, including housing, feeding, and watering. Poultry waste consists of feces, wasted feed, bedding material, litter material, feathers, soil, urine, process water, and condemned corpses (Bist et al., 2024). Numerous factors, such as the breed of poultry, the feed content, the length of time the animals are housed in the poultry house, the density of the animals, and seasonal variations, all affect the chemical composition of poultry dung and litter.

A fair amount of nitrogen, phosphorus, and other expelled materials, including antibiotics, pathogens, and heavy metals, are present in poultry feces (Neeteson-van et al., 2013). These compounds' leaching and runoff could inevitably contaminate local groundwater and surface water supplies (Himu & Raihan, 2023). Water contaminated with these pollutants might result in waterborne illnesses including diarrhea. The World Health Organization estimates that 1.8 million people die from diarrheal illness each year (Kumar & Patyal, 2020).
Excreta from poultry contain uric acid, which is converted to volatile ammonia under certain conditions. Emissions of ammonia from poultry buildings contribute to the acidification of soils and water, and can have a negative impact on populations of acid-sensitive flora (Bist & Chai, 2022).

The spread of feed crop production into natural ecosystems has indirect repercussions such as ecosystem degradation and a biodiversity catastrophe (Rodić et al., 2011). Landscape Changes in land use, cropping intensity, and crop production technologies (for example, large-scale mechanisation) can alter the kind of landscape and the mosaic of land use, vegetation types, and habitats found in the environment. Such changes have an impact on biodiversity because they alter and destroy habitats (forests, grasslands, hedgerows, wetlands) and affect the numbers and compositions of biological species present. These changes can also have an impact on the landscape's aesthetic and amenity value, which may be culturally and historically significant. Such effects are becoming more recognized in prosperous advanced nations, and they are increasingly being considered in land-use planning and environmental legislation (Gerber et al., 2006).

The next sections of this article will explore how sustainable feed ingredients can address these challenges and pave the way for a greener future in poultry production.

3. Sustainable Feed Ingredients

Sustainability is a concept that refers to meeting the needs of the present without compromising the ability of future generations to meet their own needs. It encompasses the responsible use of resources, the protection of ecosystems, and the promotion of social and economic well-being (Vaarst et al., 2015). According to the Brundtland Commission, sustainability is a broad and aspirational policy goal which includes equally significant environmental, economic, social, and institutional factors (Valentin et al., 2000).

Sustainable feed ingredients are alternative feed supplies that are grown and used in methods that reduce environmental impact, conserve natural resources, and promote long-term ecological equilibrium. These ingredients are frequently generated from renewable resources, byproducts, or innovative production methods that lessen reliance on conventional, resource-intensive crops (Bist et al., 2024). Algae and microalgae, like spirulina and chlorella, are nutrient-rich and can be cultivated using CO_2 emissions, promoting carbon recycling. Single-cell proteins (SCP), derived from yeast, bacteria, and fungi, offer efficient and scalable protein sources (Leinonen & Kyriazakis, 2016). By providing innovative and environmentally responsible substitutes for conventional chicken feeds, sustainable feed ingredients lessen the negative effects of poultry farming on the environment.

3.1. Insect-Based Proteins:

Considering their nutritional value and possible environmental benefits, utilizing insects to feed poultry birds is a viable alternative when evaluating the sustainability of this type of farming (Leinonen & Kyriazakis, 2016).One innovative method and excellent example of a sustainable circular economy is the use of insects in the bioconversion of waste materials. While there is less competitiveness between feed and food, less land is needed to produce 1 kg of protein, and organic waste can be converted into high-value protein products (Sogari et al., 2019).

Insects have recently attracted a lot of interest as a vital supply of sustainable raw materials for animal feed, particularly for pigs, poultry, and fish. According to Sajid et al. (2023), the common house fly (Musca domestica, MD), the yellow mealworm (Tenebrio molitor, TM), and the black soldier fly (Hermetia illucens, HI) are the most promising species.

Insect meal has been shown to be a rich source of protein, amino acids (lysine, methionine), and minerals (calcium, phosphorus, zinc), with a high digestibility rate, making it a valuable feed ingredient for poultry production. Mealworms and black army fly larvae are examples of insects that are high in digestibility and high in protein (35–53%), vital amino acids, and minerals (Belhadj Slimen et al., 2023**)**.

For example, Sun et al. (2013) observed that male broilers grown on grassland with a high population of grasshoppers scored much higher on chewiness, flavor, scent, and overall enjoyment for the meat of the breast and thighs than a control sample raised on a maize–soybean diet.. However, there were no appreciable variations in color or juiciness between the two treatments. As the authors noted, it was challenging to determine whether the greater sensory qualities in their trial were brought about by the grasshopper meal or by the greater dietary variety and mobility provided in a free-range setting.



Image of Insects used in poultry nutrition, (Belhadj Slimen et al., 2023).

Insect farming is resource efficient, requiring less water and land than conventional feed production, resulting in a much lower ecological imprint (Khalifah et al., 2023). The use of insect protein sources in quail diets, such as the mopane worm (Gonimbrasia belina), has demonstrated possibilities in reducing dependency on conventional protein sources, especially fish and soybean meals, while meeting the growing demand for animal protein. With an average protein content of 55% and an appropriate amino acid composition, mopane worms are a very nutrient-dense feed item. (Sajid et al., 2023).

According to research, house fly larval meal can enhance broiler performance and substitute other protein sources without negatively affecting the carcass's qualities (Khalifah et al., 2023). Countries worldwide have houseflies (HF), which can be raised on food scraps and animal dung. Significant quantities of CP and CF, ranging from 40 to 64% and 2.5 to 28%, respectively, are present in HF meal (Table 1). As HF larvae age, their CP content falls but their CF content rises (51, 52). The two amino acids that restrict poultry nutrition the most are lysine and methionine. HF meal contains substantial levels of both of these amino acids (Belhadj Slimen et al., 2023). Allowing poultry to eat insects could reduce the amount of antibiotics used in the poultry industry, given the well-established harm that antibiotics cause to both humans and the environment (the emergence of drug-resistant bacterial species) (Bist et al., 2024).

4.0 Conclusion

The adoption of sustainable feed ingredients can address critical environmental issues, while ensuring food security for a growing global population. By integrating these innovative solutions, the poultry industry can transition toward more eco-friendly responsible practices, aligning with global sustainability goals. From an economic perspective, sustainable feed ingredients not only mitigate input costs in the long run but also open avenues for value-added market differentiation, catering to consumers increasingly demanding ethically produced and environmentally friendly animal products. Additionally, regulatory frameworks and industry incentives supporting sustainability in animal agriculture reinforce the need for proactive adoption of such practices.
Ultimately, the findings of this paper underscore the imperative role of sustainable feed strategies in shaping a resilient and environmentally conscious poultry sector. Rather than being an optional innovation, sustainable feed ingredients emerge as a fundamental necessity, paving the way for a more secure, efficient, and ecologically balanced food system.

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The Role of Genomics in Improving Egg and Meat Production

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Abstract

Poultry breeding programs have been augmented with technologies such as genome-wide association (GWAS), marker-assisted selection, genomic prediction models, and genome editing (CRISPR/Cas9), creating significant advancement in productivity, resistance to diseases, and quality of products. The aim of this review is to discuss how genomics positively impacts various aspects of egg-and-meat production in poultry. The paper discusses genetic factors that influence traits of major importance, that is, growth rate, efficiency in feed conversion, muscle development, and egg-laying performance, emphasizing domestic breeding aided by molecular tools and bioinformatics as a strategy to accelerate genetic gain. Relevant findings on Norfa chickens, Japanese quail, and indigenous African poultry suggest that breeding strategies can be designed addressing both ecological constraints and economic demands. With beneficial changes, the review acknowledges some challenges, including source data complexity, the ethics of the matter, and the integration of genomic technologies into conventional breeding programs. The discoveries emphasize that meeting the increasing global demand for high-quality animal protein with utmost care for sustaining genetic diversity and resilience within poultry may call for a balanced approach combining state-of-the-art genomics with sustainable management practices.

Keywords: *Egg-meat, Genomics, molecular markers, Poultry.*

1.0 Introduction

There has been a steady increase in the global demand for animal proteins, so much so that the demand for milk and meat products is set to be at 1.25 billion tonnes by 2050 (Ritala et al., 2017) . The current increase in the search for better poultry breeding strategies for increased egg and meat production stems in part from this rising global demand (De Olde et al., 2020). As the human population increases, it applies greater pressure on the poultry industry to produce higher yields, while also regarding efficiency, sustainability, and animal welfare (Kleyn and Ciacciariello, 2021). So far, the traditional selective breeding techniques have brought dramatic improvements in genetic improvement among poultry species, pushing for improvements in productivity. However, these methods are based mainly on observable traits recorded on a long breeding cycle, which limits speed and accuracyy in genetic betterment. Proper genomics can revolutionize poultry breeding by precise genetic selection and better productivity and disease resistance.

Genomics is basically defined as the entire characterization of organisms at the level of their entire genetic makeup, and it provides many different aspects of very important insight into gene functions, interactions and its effects on economically relevant traits in poultry production (Xu et al., 2023). In fact, genomic instruments enable breeders to make genetic data-based decisions rather than phenotype driven decisions (Wolc et al., 2016). This marks a shift of superimposing phenotype-based selection toward genotype-based selection which optimizes growth rate, feed conversion efficiency, egg production, and meat quality genotype in rapid genetic gains in poultry, with further emphasis on long term genetic gain (Vanavermaete et al., 2020). With genome editing technologies like CRISPR/Cas9, genome changes can be made in livestock with efficient precision to improve desirable traits: increased milk yield or improved egg composition. A classic example is the knockout of β-lactoglobulin in dairy cattle producing milk that is hypoallergenic, but with a rich nutritional profile. These advancements greatly assist in meeting the soaring demand for food of animal origin while averting adverse environmental consequences (Yadav et al., 2024).

This review delineates research on genomics for improved egg and meat production across genomic selections, nutrigenomics, and genome-editing technologies. Through rigorous analysis and critique of research findings on the concerned subjects, this paper intends to give a clear view of the role and impact of genomics into nutrition quality, productivity, and resilience of egg and meat production against challenges presented by global food security.

2.0 Genomic Innovations in Poultry Breeding

Many modern breeding tools of genomics, such as genome-wide association studies (GWAS) and genomic selection, have opened the field to the identification and selection of better genetic lines on a much more pragmatic basis (Srivastava et al., 2020). GWAS analyses genetic differences across populations to identify genetic variants linked to important production traits. On the other hand, genomic selection applies high-density molecular markers

across the entire genome to predict an animal's breeding value with extremely high accuracy (Wolc et al., 2016; Ren et al., 2024). Compared to selection based on phenotype, genomic selection has massively boosted selection speed and accuracy in breeding programs (Vanavermaete et al., 2020). Consequently, the efficiency of poultry production has also been substantially increased. Enhancements in feed conversion ratio, assessment of skeletal development, and changes in hatchability have been attributed to genomic selection in a commercial context for overall profit in poultry production.

Improving flock health and reducing economic loss is another area where genomics comes in after productivity (Saxena and Kolluri, 2018). Poultry diseases, for example, avian influenza, Newcastle disease, and infectious bronchitis, are some of the most prominent threats to the industry, with mass mortality rates and economic blowbacks (Abdisa and Tagesu, 2017). Advances in genomic research have identified some specific markers for genetic resistance to these diseases so that poultry breeding for resistant strains can be carried out. Incorporating these markers into breeding programs have allowed breeders and poultry producers to boost the natural immunity of these birds (Cheng et al., 2013), minimizing the need for antibiotics and vaccines, which achieves two things; one is that it makes the birds mostly immune to these diseases and secondly by reducing the use of antibiotics it also reduces the cases of antimicrobial resistance, a pressing problem in the world today affecting both humans and animals (Köser et al., 2014).

Genomics influences characteristics such as tenderness, juiciness, and composition of fat on the meat because these are considered by consumers and therefore fall into market value (Leal-Gutiérrez et al., 2020). Transcriptomic analysis and expression profiling have helped researchers pinpoint the key genes involved in muscle development, lipid metabolism, and protein synthesis, for example, identifying the role of myostatin (MSTN) in muscle mass regulation and fatty acid-binding proteins (FABP) in intramuscular fat content that relates to tenderness of the meat (Bennett et al., 2019; Del Pino et al., 2020). Next, precision breeding methodologies are applied to increase the quantity and quality of poultry products while conserving genetic diversity (Huang et al., 2020).

Genomics has also played a role in egg production including laying performance, eggshell quality, and egg size (Li and Tian, 2018). Years of genetic studies have localized and mapped important regions in the genome associated with eggshell strength, yolk composition, and persistence in laying (Goto and Tsudzuki, 2017). New advances in functional genomics have broadened the understanding of genes that control reproduction efficiency, leading to the improvement of layers that have longer and more consistent laying cycles (Bain et al., 2016).

3.0 Genomics Tools and Technologies in Poultry Breeding

3.1 Molecular Genetic Approaches

The identification of candidate genes that determine major traits such as egg production, growth rate, and meat yield and has thus far been one of the most significant achievements in the field of genomics and a well-known molecular genetic approach. Radostina (2024) discussed molecular-genetic approaches in poultry breeding, stating that techniques like GWAS and microsatellite markers have been valuable accessions for establishing the association of genetic variants with traits of economic importance. GWAS, for example, enables the researcher to scan the whole genome for loci that are associated with desirable traits such as body weight or disease resistance (Ren et al., 2024). These findings build a sort of road-map for the breeders to select poultry with certain specific genetic traits relevant with market expectations. Breeders could further combine the genes in fine-tuning their selection programs, speeding up the breeding process and increasing the precision with which desirable traits are incorporated into new poultry lines (Radostina, 2024).

In the molecular genetic toolkit of poultry breeding, molecular markers play an indispensable role. These include microsatellites, single nucleotide polymorphism (SNP), and restriction fragment length polymorphism (RFLP) (Beuzen et al., 2000). Whereas microsatellites are very polymorphic and are good for genetic mapping, SNPs are very ubiquitous within the genome and are good markers of identifying the genetic variation (Miah et al., 2013).

4.0 Genetic Improvement of Egg Production in Poultry

One of the primary studies that has provided compelling evidence of genetic improvement in poultry emerges from research carried out at Menoufia University, where Norfa chickens were studied for over two generations with respect to the heritability and improvement of egg production traits. The experimental design involving the division of the base population into selected and control lines showed that further strategies of breeding aimed at egg production through a selection index method were able to enhance productivity significantly. Key management

practices such as feed adjustment and a lighting program based on "step down-step up" also played considerable roles in the optimization of laying performance in Norfa hens, indicating the equivalency of genetic versus environmental factors involved in poultry production.

In sharp contrast, a long-term study was also performed on Japanese quail (Nandanam quail-3) across six generations to improve egg production traits through a multi-stage selection process (Pandian et al., 2022). Here, the report showed that hen housed egg production had been significantly enhanced with an increase from 202 to 220 eggs over 40 weeks of laying, with a high goodness of fit ($R^2 = 0.97$). Notably, a negative correlation was exhibited between body weight and egg production traits, which, the multi-stage selection strategy successfully addressed, resulting in enhancement of both traits.

4.1 Indigenous Chicken Production and Disease Resistance

Research by Zhou et al. (2024) explored the enhancement of egg production traits in African village chickens, with an emphasis on resilience to Newcastle disease (ND). The Feed the Future Innovation Lab for Genomics to Improve Poultry developed a genetic selection platform designed to improve survival rates, reduce virus shedding, and enhance both growth rates and egg production in these chickens. Unlike the controlled breeding environments of the Norfa and Japanese quail studies, this research highlighted the challenges posed by real-world production systems, where disease resistance and adaptability to environmental stressors are critical. The study's findings suggest that integrating genetic selection for ND resistance with traditional vaccination and biosecurity measures offers a promising avenue for improving egg production in indigenous poultry lines.

4.2 Genome-Wide Association Study in Qingyuan Partridge Chickens

Another level of insight was brought into genetic improvement for egg production by the recent genome-wide association study (GWAS) done on Qingyuan partridge chickens (Kang et al. in 2024). The research identified MTA2 as a potential new candidate gene responsible for the egg laying rate in laying hens. Notably, this is the first time that this gene has been associated with traits for egg production in chickens. Further, one genomic-significant SNP and three chromosomal significant single nucleotide polymorphisms (SNPs) correlated with egg laying rate were found, indicating that whole genome resequencing is an efficient way to identify genetic markers accurately. The genetic enhancement of traits pertaining to egg production can be furthered by molecular genetics techniques.

5.0 Genetic Improvement of Meat Production in Poultry

Growth rate and feed conversion ratio (FCR) are two very economically relevant traits in broiler chickens. Selection programs have seen much progress in the improvement of these traits over the past several decades. Genetic factors concerning growth are associated with key regions of the chicken genome; comparatively, quantitative trait loci (QTL) studies indicate specific markers for faster weight gain and better feed efficiency (Cahyadi et al., 2014). For example, the insulin-like growth factor-I (IGF1) gene is vital for growth and feed utilization. By means of marker-assisted selection (MAS), the favourable alleles of IGF1 and similar genes can be incorporated by the breeder to improve growth performance without compromising health or reproductive traits (Dou et al., 2022).

Genomic selection, in addition to being based on estimated breeding values (EBVs), allows for multiple-trait advancement such as rapid growth with optimal FCR while avoiding adverse effects such as leg disorders or cardiovascular problems (Xu et al., 2020). Thus, the entire concept is about making genetic progress that will sustain the poultry producer and also be good for the bird (Fleming et al., 2007).

5.1 Muscle Development and Meat Quality

A key aspect of genetic enhancement in broiler chickens refer to muscle development and meat quality. Rapid growth is desirable but needs to be combined with the required texture, flavour, and tenderness of meat, according to consumer preferences (Mir et al., 2017). Many candidate myogenic genes and muscle fibre characteristics have been identified through advanced techniques in molecular genetics (Joo et al., 2013). For instance, the myostatin (MSTN) gene is one of the most prominent muscle regulators, and MSTN inhibition or downregulation can result in an increase in muscle mass—an indicator in the meat production feature. Expression of MSTN must be done carefully to eliminate problems such as muscle hypertrophy that adversely affect meat quality or animal welfare.

Additionally, genes regulating postmortem glycolysis in muscle pH, for example, AMP-activated protein kinase (AMPK) pathway genes, also play major roles in the tenderness of meat and water-holding capacity (Scheffler et al., 2011). Breeders can select for favourable variants of these genes to gain benefits from both yield and sensory quality of poultry meat.

5.2 Fat Deposition and Carcass Quality

As we understand it, fat distribution and carcass yield are the most important traits in broiler production, influencing processing efficiency and, hence, consumer satisfaction (Mir et al., 2017). According to Moreira et al. (2018), Genomics research has reported much of the genetic understanding of the mechanisms whereby fat is deposited and lean meat is produced, such that more accurate selection for these traits is now possible. The gene involved in peroxisome proliferator-activated receptor gamma (PPARG) marks the entry point in the regulation of adipogenesis, making mutations here consequential to the regulation of the balance between fat and muscle growth (Fredenrich and Grimaldi, 2004). Thus, breeders could increase the quality of carcasses by excluding alleles caused by excessive fat deposition, which leads to increased feed inefficiency. From GWAS, SNPs have been detected that were significantly associated with abdominal fat percentage and breast muscle yield, two of the major traits considered in the optimization of broiler carcass composition.

6.0 Challenges and Limitations of Genomic Applications

The sheer complexity of genomic data is one of the most remarkable technical barriers. The bulk of information produced by genomic sequencing makes its accurate analysis and interpretation rather tedious and, thus, tends to create delays and even possible misdiagnoses. Moreover, protein stability prediction—an important factor with respect to precision medicine—is still a challenging exercise mostly because of scant thermodynamic data and variability in experimental conditions. This lack of predictively accurate assays precludes the establishment of definitive therapeutic interventions pertaining to proteins for research use (Sanavia et al., 2020).

7.0 Conclusion

The genetic improvement of poultry production, whether for egg or meat yield, represents a remarkable convergence of traditional breeding practices and modern genomic technologies. It enhances productivity, disease resistance, and economic viability in poultry farming. Techniques like selective breeding, molecular genetics, and genome-wide association studies (GWAS) optimize egg and meat production traits, even in the face of environmental and disease-related challenges. However, challenges such as data complexity, ethical considerations, and organizational difficulties present challenges. As genomic technologies continue to evolve, their thoughtful application promises to shape a more efficient and resilient poultry industry, supporting global food security and economic development.

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Utilization Of Urban Agricultural Practices In Osogbo Metropolis Osun State, Nigeria

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Abstract

Urban agriculture is fundamental to Nigeria's economy, as it addresses the pressing issues of food insecurity, rapid urbanization, and environmental degradation and promotes sustainable livelihoods, hence, this study assessed the utilization of urban agricultural practices in Osogbo metropolis. Specifically, it described the socio-economic characteristics of the respondents, identified the urban farming practices in the study area, as well as the level of utilization of these practices and constraints facing utilization of urban agricultural practices. To accomplish the objectives of the study, data was collected with the aid of a well-structured interview schedule and snowballing was used to generate a sampling frame and, consequently, random sampling to obtain 83 respondents as the sample size. Data collected was analyzed using frequency counts, percentages and mean while Pearson product moment correlation (PPMC) was used to test the hypothesis. Result revealed that Urban livestock is very popular in the study area, while Aquaponics and hydroponics attracted less attention. Women participated more in urban agricultural practices, as 60.2% of the respondents were female, also, respondents earned a substantial amount of money from urban agriculture. Regulatory restriction, Initial investment cost and Limited space were the constraints facing the utilization of urban agricultural practices. There was significant relationship between annual income ($r= 0.247$, $p= 0.024$) and level of utilization of urban agricultural practices. The study concluded that many urban dwellers in Osogbo metropolis practiced urban agriculture, such as urban livestock and culinary gardens, but faced problems of regulatory restrictions, initial investment cost and limited space. The study recommends that, the extension services of Osun State Agricultural Development Programme should be extended to those practicing urban agriculture, this will go a long way in improving and sustaining households' livelihoods.

Keywords: Urban**,** Agriculture**,** Urban Agriculture, Utilization**,** Urban Farming

Introduction

Urban agriculture can be referred to as small areas within cities, such as vacant lots, gardens, verges, balconies and containers, that are used for growing crops and raising small livestock or milk cows for own-consumption or sale in neighborhood markets (Poulsen *et al.,* 2015). However, the global urban population has been expanding rapidly over the last few decades, in early 2010s, half of the world's population was living in cities (The World Bank, 2014). This proportion is expected to reach 70 percent by 2050 mainly driven by the growing urbanization in the developing world, particularly in sub-Saharan Africa (SSA) (FAO, 2012; Poulsen *et al.,* 2015). By the end of the current decade, 24 of the world's 30 fastest growing cities will be African, and within 18 years, the urban population of SSA is projected to reach almost 600 million, twice how much it was in 2010 (FAO, 2012). As a result of this rapid urbanization, ensuring food security of urban residents has become a critical challenge (Poulsen *et al.,* 2015) and the focus of food insecurity has shifted and expanded from rural to urban areas (Davies *et al.,* 2020).

Urban Agriculture has a potential to increase food security in several ways (Poulsen *et al*., 2015). First, it may create easier and stable access to nutritious food for those households producing their own food (Binns *et al*, 2013). Secondly, household may be able to generate additional income by selling their products and hence improve their livelihood (Redwood, 2009). Third, it could help to improve food security of the community by increasing the total production output available in the market (Poulsen *et al*. 2015).

The urban mass exodus which is exacerbated by migrants of able-bodied men and youth leaving the disadvantaged groups (women, children, elderly, retired and people terminally ill) in the rural areas to perform agricultural operations with simple implements which cannot sustain their subsistence production let alone for supply to the cities (Adedayo and Tunde, 2012) had led to hunger and starvation in the land, hence, there is need to increase food production in urban space to meet up urban food requirement. Therefore, this study examined the utilization of Urban Agriculture in Osogbo metropolis, the study describes the socio-economic characteristics of the respondents; examined the level of utilization of urban agricultural practices and investigate the constraints facing utilization of urban agricultural practices in the study area.

Methodology

This study was carried out in Osogbo metropolis, in Osun state, Nigeria. This study makes use of a two-stage sampling technique, the first stage involved the purposive selection of three communities from the two local government areas that made up Osogbo and its environ, and that are well known with urban farming, the selected communities includes Oke-oniti, Oke-Bale and Oke-Ayepe. Snowballing was used to generate sampling frame and consequently random sampling to obtain 83 respondents as sample size.

Results And Discussion

Socio-Economic Characteristics Of The Respondents

Data presented in table 1 revealed the following information, 5% of the respondents fall under the age of 20 years, 38.4% were between the ages of 21-40 years, 36.0% were between the ages of 41-60 years of age, while 20.4% claimed to be above 60 years, as their mean age sum up to be 45.30. This is indicative that people that are full of vigor and strength are more involved in urban agriculture. Olofin (2006) established that farmers between 30 and 70 years of age undertake urban crop production. Also, 39.8% of the respondents were male, while 60.2% were female, this implies that women participated more in urban agricultural practices.

Table 1: Distribution of the respondents according to their socio-economic characteristics n=84

Socio-Economic Characteristics	Frequency	Percentage	Mean
Age (years)			
≤ 20	5	4.8	
21-40	32	38.4	
41-60	30	36.0	45.30
61 & above	17	20.4	
Sex			
Male	34	39.8	
Female	50	60.2	
Marital status			
Single	16	19.3	
Separated	3	2.4	
Divorced	2	2.4	
Widow	7	8.4	
Married	56	67.5	
Religion			
Islam	27	32.5	
Christianity	48	57.8	
Traditional	9	9.6	
Academic qualification			
Primary school	8	8.4	
Secondary	29	34.9	3.5
Tertiary	47	56.6	
Secondary occupation			
Farming	27	35.5	
Artisan	27	35.5	
Trading	22	26.5	
Transport service	5	6.0	
Clergy	3	2.4	
Household size (persons)			
≤ 5	36	43.4	
6-9	38	43.9	2.1
10 and above	10	10.8	
Annual income (#)			
0-300, 000	47	56.6	356103
300001-600,000	26	31.2	
Social organization			
No	39	47.0	
Yes	45	53.0	

Source: Field survey, 2024.

This result agreed with the findings of Paola (2003), who reported that women are more dominant in farming due to the fact that they are responsible in feeding the family, also table 1 further revealed that 67.5% of the respondents were married, 19.3% claimed to be single, 8.4% were widow while 3% were separated.
Furthermore, 57.8% of these respondents were Christians, 32.5% Muslims, while very few 8.4% claimed to be traditional worshipers, more than half, 56.6% of the respondents had tertiary education, 34.9% had secondary school education, while very few 8.4% had primary school education, this implies that the respondents in the study area are well learned. Also 35.3% of the respondents claimed farming and artisan as their secondary occupation, 26.5% claimed trading, 6.0% claimed transport services, while very few 2.4% were clergy. Also 43.4% of these respondents had up to 5 individuals in their household, 45.9% had between the 6- 9, while very few 10.8% had up to 9 individuals in their home.
Lastly table 1 revealed the annual income of the respondents from urban agriculture, 56.6% earned up to #300,000, also 31.2% earned between #300001,00 to #600,000, also 4.8% earned between #60001- #800,000, while 7.2% earned up to 800001 and above .Also 53.0% of the respondents claimed to belong to social organization.

Level Of Utilization Of Urban Agricultural Practices

The result presented in Table 2 showed the level of Utilization of Urban Agricultural practices among the respondents, the most utilized practice to the least utilized was rank using Weigh mean score. Urban livestock ranked first as the most utilize practice with a Weighted mean score of 1.80, Culinary gardens in second with a WMS of 1.39, Aquaponics ranked third with a WMS of 1.16, Backyard snail farming with a WMS of 0.69 ranked fourth, Hydroponics ranked fifth with a WMS of 0.36, while Community gardens and Seed libraries ranked least in sixth and seventh with a WMS of 0.25 and 0.22 respectively. This implied that among the selected agricultural practices, Urban livestock and Culinary gardens is the most utilized practices. This is in agreement with the findings of Olumba, *et al.,* (2021) who found poultry as the prominent livestock raised by urban farmers in Southeast Nigeria.

Constraints Facing Utilization Of Urban Agricultural Practices

The result presented in Table 3 showed the constraints facing utilization of Urban agricultural practices, the constraints was ranked from highest to least using Weighted mean score, Regulatory restriction ranked first with a WMS of 1.19, Initial investment cost ranked second with a WMS of 1.04, Limited space ranked third with a WMS of 0.96, Improper sewage disposal, Incomplete information about urban agriculture, Water access, Incomplete information, about urban agriculture, Inadequate equipment to practice, Lack of technical know-how, Limited access to extension services, Water quality were are ranked 4th, 5th, 6th, 7th, 8th, 9th,and 10th with a WMS of 0.88, 0.86, 0.84, 0.83, 0.83, 0.75, 0.53, and 0.14 respectively, while High cost of soil management ranked least in eleventh with a WMS of 0.05. This implies that majority of urban dwellers would have love to participate in urban agriculture, but face problem like Regulatory restriction and Initial investment cost, this may be so, because most of the urban areas in Nigeria are guiding by strict laws that might not permit these practices.

Table 2: Distribution of the respondents according to the Level of Utilization of Urban Agricultural practices

Practices *	Always utilized	Moderately utilized	Occasionally utilized	Not utilized	WMS	Rank
Urban livestock	29 (34.9)	30(36.1)	3(2.4)	22(26.5)	1.80	1st
Culinary gardens	17(20.5)	31(37.3)	3(2.4)	33(39.8)	1.39	2nd
Aquaponics	15(18.1)	23(27.7)	6(6.0)	40(48.2)	1.16	3rd
Backyard snail farming	6(6.0)	20(24.1)	2(2.4)	56(67.5)	0.69	4th
Hydroponics	3(2.4)	9(10.08)	6(7.2)	66(79.5)	0.36	5th
Community gardens	3(2.4)	5(6.0)	5(6.0)	71(85.5)	0.25	6th
Seed libraries	3(3.6)	3(3.6)	3(3.6)	75(89.2)	0.22	7th

Source: Field survey, 2024. *Multiple Response

Table 3: Distribution of the respondents according to the Constraint facing utilization of urban agricultural practices

Constraints	Serious	Mild	Not a problem	WMS	Rank
Regulatory restriction	30(36.1)	40(47.0)	14(16.9)	1.19	1st
Initial investment	29(33.7)	30(36.1)	25(30.1)	1.04	2nd
Limited space	12(13.3)	58(69.9)	14(16.9)	0.96	3rd
Improper sewage disposal	12(13.3)	51(61.4)	21(25.3)	0.88	4th
Incomplete information about urban agriculture	12(13.3)	49(59.0)	23(27.7)	0.86	5th
Water access	17(19.3)	30(36.1)	37(44.6)	0.84	6th
Inadequate equipment to practice	5(6.0)	60(71.1)	19(22.9)	0.83	7th
Lack of technical know-how	17(19.3)	30(36.1)	37(44.6)	0.75	8th
Limited access to extension services	9(9.6)	28(33.7)	47(56.6)	0.53	9th
Water quality	3(2.4)	8(9.6)	73(88.0)	0.14	10th
High cost of soil management	2(1.2)	2(2.4)	80(96.4)	0.05	11th

Source: Field survey, 2024 *Multiple Response

Hypothesis Testing

Pearson product moment Correlation analysis of the relationship between the socio-economic characteristics of the respondents and level of utilization of urban agricultural practices.

Data presented in Table 4 shows that, there is a positive and significant relationship between annual income (r= 0.247, p= 0.024) and level of utilization of urban agricultural practices. This implies that the more the respondents realizes from this practices the more they engage in it, also this result means that irrespective of the standard of living of the respondents before engaging in urban agriculture, they considered their standard of living to have been better than others after engaging in urban agriculture. This finding agrees with that of Mupeta *et. al.* (2020), that the income of households that practiced urban agriculture increased from 13.7% to 19.1%. It implies that urban agriculture has the potential to improve household standard of living through enhanced income.

Table 4: PPMC showing the relationship between selected socio-economic characteristics of the respondents and level of utilization of urban agricultural practices

Variables	r- value	p- value	Remark
Age	0.126	0.257	Not significant
Academic qualification	0.042	0.707	Not significant
Annual income	0.247*	0.024	Significant

Source: Computed data, 2024.
*correlation is significant at the 0.05 level (2 tailed)

Conclusion And Recommendation

Based on this research findings, it can be concluded that, many urban dwellers were practicing urban agriculture such as urban livestock and culinary gardens and but faced problem of regulatory restrictions, initial investment cost as well as Limited space.

Form findings made during this research work, it is recommended that extension services of Osun State Agricultural Development Programme should be extended to those practicing urban agriculture. This will go a long way in improving and sustaining households' livelihoods.

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Biosurfactant Production by *Aeromonas caviae*

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Abstract

Surfactants are amphiphilic compounds known as surface-active agents. Due to this property, they accumulate at the interfaces of different phases and reduce the surface tension between these phases, facilitating their mixing and the formation of emulsions. Consequently, surfactants have widespread applications in detergents and cleaning products, the food industry, cosmetics and personal care products, the oil and gas industry, as well as in medicine and pharmaceuticals. However, these synthetic surfactants, which are chemically synthesized, have certain adverse effects on both the environment and human health. Therefore, biosurfactants, which are naturally synthesized by bacteria, fungi, and other microorganisms, have gained significant importance as alternatives to synthetic surfactants. Eco-friendly biosurfactants offer several advantages, including low toxicity, biodegradability, high biocompatibility, sustainable production, and stability under various conditions. Additionally, their diversity makes them a promising group of compounds for a wide range of industrial and biotechnological applications. This study aims to investigate the biosurfactant production potential of the Aeromonas caviae LipT51 strain. Biosurfactants are increasingly attracting interest in biotechnology due to their advantages, such as low toxicity, biodegradability, and environmental compatibility. In this study, *A. caviae* LipT51 was cultured in a medium containing olive oil to induce biosurfactant production. The presence of biosurfactant production was confirmed through various tests, including the Parafilm M test, oil spreading test, emulsification index (E24) measurement, CTAB agar method, hemolytic activity test, foam formation test, and phenol-sulfuric acid method. The results demonstrated that the produced biosurfactant exhibited surface-active properties, possessed emulsification capacity, and showed potential for biotechnological applications, including hydrocarbon bioremediation and antimicrobial activity.

Key Words: *Biosurfactant, Aeromonas caviae, surface active agents, biotechnology*

Aeromonas caviae ile Biyosürfaktan Üretimi

Özet

Sürfaktanlar, yüzey aktif maddeler olarak bilinen amfifilik bileşiklerdir. Bu özellikleriyle farklı fazlar arasındaki yüzeylerde birikir ve bu fazlar arasındaki yüzey gerilimini azaltarak bunların daha kolay karışmasını ve emülsiyon oluşumunu sağlar. Bu sayede sürfaktanlar deterjan ve temizlik ürünleri, gıda endüstrisi, kozmetik ve kişisel bakım ürünleri, petrol ve gaz endüstrisi, tıp ve ilaç endüstrisinde geniş kullanım alanlarına sahiptir. Ancak, kimyasal olarak sentezlenen bu sentetik sürfaktanlar çevresel ve sağlık açısından bazı olumsuz etkilere sahiplerdir. Bu yüzden, sürfaktanlara alternatif olarak genellikle bakteriler, mantarlar ve diğer mikroorganizmalar tarafından doğal olarak sentezlenen biyosürfaktanlar büyük önem kazanmıştır. Çevre dostu biyosürfaktanlar düşük toksisite, biyolojik olarak parçalanabilirlik, yüksek biyouyumluluk, sürdürülebilir üretim, farklı koşullarda kararlılık gibi avantajlara sahiptir. Ayrıca, biyosürfaktanların çeşitliliği, onları geniş bir endüstriyel ve biyoteknolojik uygulama yelpazesinde potansiyel olarak kullanılabilir bir bileşik grubu haline getirir. Bu çalışma ise *Aeromonas caviae* LipT51 suşunun biyosürfaktan üretim potansiyelini araştırmayı amaçlamaktadır. Biyosürfaktanlar, düşük toksisite, biyobozunurluk ve çevresel uyumluluk gibi avantajları nedeniyle biyoteknolojide giderek daha fazla ilgi görmektedir. *A. caviae* LipT51 zeytinyağı içeren besi ortamında kültüre edilerek biyosürfaktan üretimi gerçekleştirilmiştir. Parafilm M testi, yağ yayma testi, E24 emülsifikasyon indeksi ölçümü, CTAB agar yöntemi hemolitik aktivite testi, köpüklenme testi ve fenol sülfirik asit yöntemi ile biyosürfaktan üretimi doğrulanmıştır. Yapılan testler sonucunda, üretilen biyosürfaktanın yüzey aktif özellikler gösterdiği, emülsifikasyon kapasitesine sahip olduğu ve hidrokarbon bioremediasyonu, antimikrobiyal etkisi ile biyoteknolojik uygulamalar için potansiyel taşıdığı belirlenmiştir.

Anahtar Kelimeler: *Biyosürfaktan, Aeromonas caviae, yüzey aktif bileşikler, biyoteknoloji*

Giriş

Sürfaktanlar, yüzey aktif maddeler olarak bilinen bileşiklerdir ve hem hidrofilik (suyu seven) hem de hidrofobik (sudan kaçınan) bileşenlere sahip olmaları sayesinde farklı fazlar arasında yüzey gerilimini azaltma özelliği gösterirler. Moleküler yapılarındaki hidrofilik baş kısmı genellikle şeker, amino asit, fosfat, karboksilik asit veya alkol gibi polar fonksiyonel gruplardan oluşurken, hidrofobik kuyruk kısmı ise genellikle β-hidroksi yağ asitlerinin hidrokarbon zincirlerini içerir (Banat et al., 2010).

Amfifilik özellikleri nedeniyle sürfaktanlar, sıvı/katı, sıvı/gaz ve sıvı/sıvı (yağ/su) gibi farklı fazlar arasındaki yüzeylerde birikir ve bu fazlar arasındaki yüzey gerilimini azaltarak bunların daha kolay karışmasını ve etkileşime girmesini sağlar. Bu yüzey aktif özellikleri, onları evsel kullanımlarından endüstriyel süreçlere ve tarımsal uygulamalara kadar geniş bir kullanım alanına sahip çok yönlü kimyasal bileşikler haline getirmektedir (Pierre et al., 2025).

Kimyasal olarak sentezlenen sürfaktanlara alternatif olan biyosürfaktanlar da büyük önem taşır. Biyosürfaktanlar, bakteriler, mantarlar ve diğer mikroorganizmalar tarafından doğal olarak sentezlenen yüzey aktif biyomoleküllerdir ve düşük toksisite, biyolojik olarak parçalanabilirlik, çevresel uyumluluk gibi avantajlara sahiptir. Ayrıca, yüksek köpürme kapasitesi, seçicilik ve sıcaklık, pH ve tuzluluk gibi çevresel faktörlere karşı direnç gibi özellikleri ile endüstriyel ve çevresel uygulamalarda büyük bir potansiyel taşımaktadırlar (Adetunji, 2022; Kumar and Dubey, 2023; Kugaji et al., 2025).

Biyosürfaktanlar kimyasal sürfaktanlara kıyasla çevre dostu ve biyolojik olarak parçalanabilir olduklarından, özellikle son yıllarda sürdürülebilir alternatifler olarak büyük ilgi görmektedir. Su-yağ ara yüzeylerinde emülsiyonlar oluşturabilme, köpük stabilizasyonu, biyofilm inhibisyonu ve kirleticilerin uzaklaştırılması gibi özellikleri sayesinde çevresel, tıbbi ve endüstriyel birçok alanda yaygın şekilde kullanılmaktadırlar. Glikolipidler, lipopeptitler, fosfolipidler, yağ asitleri, lipidler, polimerik sürfaktanlar ve partikül sürfaktanlar gibi çeşitli alt gruplara ayrılan biyosürfaktanlar, sahip oldukları geniş substrat erişilebilirliği sayesinde ticari uygulamalarda önemli bir potansiyel sunmaktadır (Jahan et al., 2020).

Biyosürfaktanların sunduğu geniş fonksiyonel çeşitlilik, onları farklı endüstrilerde uygulama alanı bulabilen değerli bileşikler haline getirmektedir. Tarım, çevre, tıp, gıda ve petrol sanayisi gibi birçok sektörde kullanılan biyosürfaktanlar, antiviral, antifungal ve antibakteriyel etkileri nedeniyle sağlık ve kozmetik ürünlerinde de değerlendirilmektedir (Gürkök and Özdal, 2021; Ozdal et al., 2023; Kugaji et al., 2025).

Yağ-su emülsiyonlarının stabilitesini artırarak biyosürfaktanlar gıda ürünlerinin raf ömrünü uzatmada, margarin, dondurma, mayonez gibi emülsifiye gıdalarda kullanılabilir. Gıda patojenlerine karşı antimikrobiyal ve antibiyofilm özellikler göstererek doğal koruyucu ajan olarak işlev görebilir ve gıda güvenliğini artırırlar. Bu özellikleriyle ayrıca tarımda bitki hastalıklarına neden olan bazı mantar ve bakterilere karşı zararlı karşı biyolojik mücadelede kullanılabilirler. Emülsifiye edici özellikleriyle topraktaki besin maddelerinin biyoyararlanımını artırarak bitki büyümesini teşvik edebilir ve pestisit ve ağır metal gibi kirleticilerin topraktan uzaklaştırılmasına yardımcı olabilirler (Adetunji, 2022; Sharma et al., 2025).

Aeromonas caviae LipT51 suşu bir kaplıcadan izole edilmiş olup, yüksek sıcaklık ve alkali koşullara dayanıklı bir lipaz enzimi ürettiği bildirilmiştir. Bu çalışmada ise *A. caviae* LipT51'in zeytinyağı içeren besi ortamında biyosürfaktan üretiminin araştırılması amaçlanmıştır.

Materyal ve Yöntem

Bakteri Kültürü ve Besiyeri Koşulları

Aeromonas caviae LipT51 (GenBank ID: MN818567.1) daha önce tamamlanmış bir proje kapsamında Erzurum İli'ndeki bir kaplıcadan izole edilmiştir. *A. caviae* LipT51 suşu, nutrient agar besiyerine ekilerek 30 °C'de inkübe edilerek çoğaltılmıştır. Ön kültür, Nutrient Broth (NB) ortamında bir gece inkübe edilerek hazırlanmıştır. Biyosürfaktan üretimi için %1 zeytinyağı içeren NB besiyeri kullanılmış ve kültürler 30 °C'de, 180 rpm'de çalkalamalı inkübasyona tabi tutulmuştur. Ayrıca, %0,5, 1, 2 ve 5 konsantrasyonlarında zeytinyağı içeren besi ortamlarında geliştirilerek *A. caviae* LipT51'in biyosürfaktan üretimi üzerine yağ miktarının etkisi incelenmiştir.

Biyosürfaktan Üretimi ve Hasat

Kültürler dört gün boyunca inkübe edildikten sonra, biyosürfaktan analizleri başlatılmıştır. Biyosürfaktan varlığının tespiti için bakteri kültürleri 10.000 rpm'de 20 dakika santrifüj edilmiş ve analizlerde hücresiz kültür süpernatantı kullanılmıştır.

Biyosürfaktan Varlığının Analizi
Üretilen biyosürfaktanın yüzey aktif özelliklerini değerlendirmek için çeşitli testler uygulanmıştır. Bu analizlerde pozitif kontrol (+) olarak %1'lik SDS ve negatif kontrol (+) olarak distile su kullanılmıştır.

Parafilm M Testi
Biyosürfaktan varlığını değerlendirmek için kullanıllan parafilm M testinde kültür süpernatantından 25 µL alınarak parafilm yüzeyine damlatılarak yayılma özellikleri gözlemlenmiştir ve kontrol numuneleri ile karşılaştırılmıştır. Pozitif kontrol olarak %1'lik SDS ve negatif kontrol olarak distile su kullanılmıştır (Gurkok and Ozdal, 2023).

Emülsifikasyon İndeksi (E24)
Yağ-su arayüzünde emülsiyon oluşturma kapasitesini belirlemek için %1 zeytinyağında kültüre edilen A. caviae süpernatantı kullanılmış ve emülsiyon stabilitesi ölçülmüştür. Bir tüp içerisine 2 mL süpernatant ve 2 mL zeytinyağı konularak ve vorteksle 2 dakika boyunca iyice karıştırılmıştır. Ardından 24 saat dinlendirilmiştir. Süre sonunda E24 ölçümleri aşağıdaki denkleme göre hesaplanmıştır (Cooper and Goldenberg, 1987; Gurkok, 2022).
E24 (%)= (Emülsiyon tabakasının yüksekliği/Toplam yükseklik) x 100

Yağ yer değiştirme Testi
Biyosürfaktanın yağ yer değiştirme testi 9 cm çapa sahip petri kaplarında gerçekleştirilmiştir. 20 mL distile su petri kaplarına konuşmuş ve üzerine 500 µL zeytinyağı eklenerek bir tabaka oluşturulmuştur. Yağ tabakasının ortasına 15 µL kültür süpernatanı aktarılmıştır. Yağ tabakasının üzerinde oluşan zon çapı cetvelle ölçülmüştür (Morikawa et al., 2000). Zon çapı 0.5-0.9 cm ise '+', 1-1.5 cm ise '++', 1.5-2.1 cm aralığında ise '+++', 2.1 cm'den büyük ise '++++' olarak değerlendirilmiştir.

Hemolitik Aktivite Testi
A. caviae bakterisi kanlı agar (%5 koyun kanı içeren) petrilerine ekildi ve 37 °C'de 2-3 gün boyunca inkübe edildi. Sürenin sonunda kan hücrelerinin hemolizine bağlı olarak kolonilerin etrafında zon oluşumu izlendi (Mulligan et al. 1984; Gurkok, 2022).

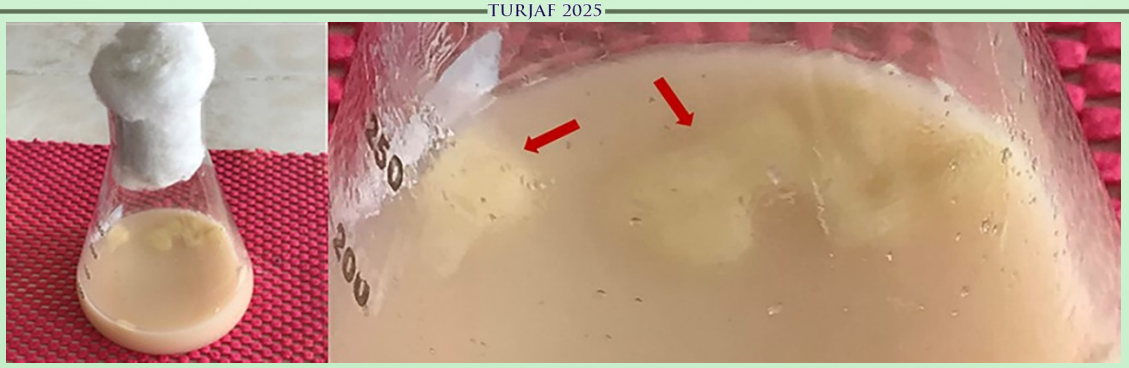
Köpüklenme Testi
Biyosürfaktanın köpük oluşturma kapasitesini ölçmek için 5 mL kültür süpernatantı 2 dakika boyunca kuvvetli bir şekilde çalkalandı ve köpüklenme aşağıdaki denkleme göre hesaplandı (El-Sheshtawy & Doheim, 2014).
Köpüklenme (%) = Köpük yüksekliği / Toplam yükseklik x 100

Fenol-Sülfürik Asit Yöntemi
Karbonhidrat bazlı biyosürfaktan varlığını belirlemek amacıyla gerçekleştirilmiştir. *A. caviae* LipT51 kültür süpernatantından 400 µL alınarak, 200 µL fenol ve 1000 µL H_2SO_4 ile karıştırılmıştır. Karışım soğutulduktan sonra spektrofotometrede 480 nm'de optik yoğunlukları (OD) ölçülmüştür. Karbonhidrat miktarı 0-150 mg/L konsantrasyon aralığında hazırlanan ramnoz standart eğrisi kullanılarak hesaplanmıştır (Ozdal et al., 2017).

Atık Ayçiçek yağı ile Biyosürfaktan Üretimi
Hem daha ekonomik biyosürfaktan üretimi elde etmek hem de atık maddelerin değerlendirilmesi amacıyla farklı miktarlarda (%0,5, 1, 2, ve 5) atık ayçiçek yağı içeren kültürlerdeki biyosürfaktan üretimleri araştırılmıştır. Fenol sülfrik asit yöntemiyle miktar tayini gerçekleştirlmiştir.

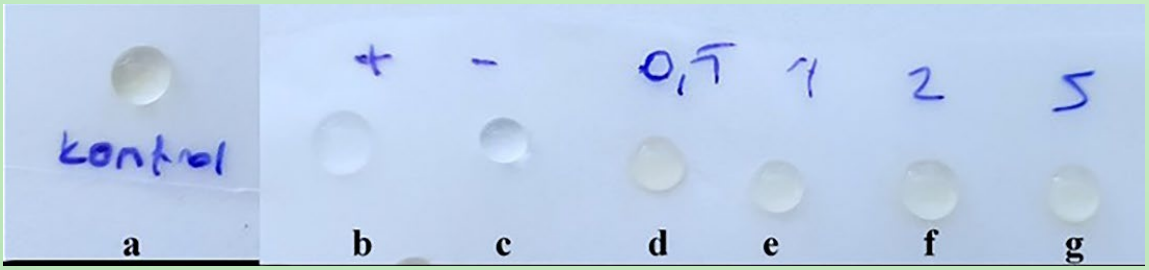
Bulgular ve Tartışma

***A. caviae* LipT51 ile biyosürfaktan üretimi**
A. caviae LipT51'in %1 zeytinyağı içeren NB besiyerinde inkübasyonu sonucunda Şekil 1'de görüldüğü gibi kültür yüzeyinde bazı metabolik ürünlerin biriktiği, santrifüj edildiğinde kolaylıkla çökmediği ve SDS gibi kimyasal sürfaktantlara benzer yüzey aktivitesi gösterdiği görülmüştür.



Şekil 1. %1 zeytinyağı içeren NB besiyerinde gelişen *A. caviae* Lip51 kültür yüzeyinde gözlemlenen yüzey aktif madde

A. caviae LipT51 ile biyosürfaktan üretimi öncelikle parafilm-M testi kullanılarak incelenmiştir. Şekil 2'de görüldüğü gibi, %0,5, 1, 2 ve 5 oranlarındaki zeytinyağlı besi ortamlarında büyütülen *A. caviae* LipT51 kültüründen elde edilen süpernatantların parafilm yüzeyinde yayılma gösterdiği tespit edilmiştir. Buna karşın, negatif kontrol grubunda ve yağ içermeyen (%0) kontrol kültüründe herhangi bir yayılma gözlenmemiştir.



Şekil 2. Parafilm M testi. Kontrol besiyeri (a), pozitif kontrol SDS (b), negatif kontrol H_2O (c) ile %0,5 (d), %1 (e), %2 (f), ve %5 (g) zeytinyağı içeren besiyerinde gelişen *A. caviae* LipT51 süpernatantı

A. caviae LipT51 süpernatantı kullanılarak gerçekleştirilen yağ yayma testi sonucunda Şekil 3'de gösterildiği üzere, kültür süpernatantı hem petri yüzeyine yerleştirilen zeytinyağı hem de motor yağı üzerinde yayılma sağlamıştır. Buna ek olarak, farklı yağ konsantrasyonlarının etkisini değerlendirmek amacıyla %0,5, 1, 2 ve 5 zeytinyağı içeren besi ortamlarında geliştirilen *A. caviae* LipT51 kültürüne ait süpernatantlarla yağ yayma testi gerçekleştirilmiştir. Test sonucunda, biyosürfaktan varlığına bağlı olarak oluşan şeffaf zon çapları ölçülerek Tablo 6'da sunulmuştur. Kontrol grubunda herhangi bir yağ yayılması gözlemlenmezken, en yüksek yağ yayma aktivitesi %2 ve %5 oranında zeytinyağı içeren ortamlarda tespit edilmiştir.

Tablo 1. Farklı zeytinyağı içeren besiortamlarında gelişen *A. caviae* LipT51 kültür süpernatantlarının yağ yayma aktivitesinin ve zon çaplarının belirlenmesi

Numune	Zon Çapı (cm)	Yağ Yayma Aktivitesi
Kontrol	0	-
%0.5 Zeytinyağı	1.2	++
%1 Zeytinyağı	1.7	+++
%2 Zeytinyağı	2.3	++++
%5 Zeytinyağı	2.8	++++

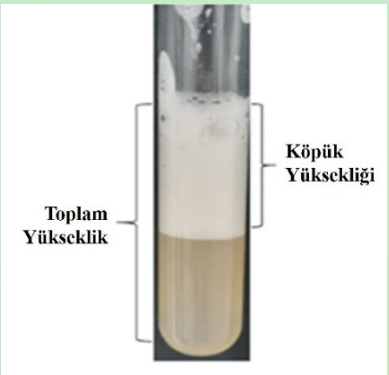
Kanlı agar petrisi üzerinde gelişen *A. caviae* LipT51'in kolonileri etrafında oluşturduğu şeffaf zon Şekil 3'de gösterilmiştir. *A. caviae* LipT51'in hemolitik aktiviteye sahip olması eritrositlerin hemolizine neden olan biyosürfaktan maddenin üretiminin bir göstergesi olarak değerlendirilmiştir.

Şekil 3'de kanlı agar petrisinde gelişen *A. caviae* LipT51 kolonilerinin çevresinde oluşan şeffaf zon gösterilmiştir. Bu şeffaf alan, bakterinin hemolitik aktiviteye sahip olduğunu ve eritrositlerin hemolizine neden olan biyosürfaktan üretiminin bir göstergesi olarak değerlendirilmektedir.



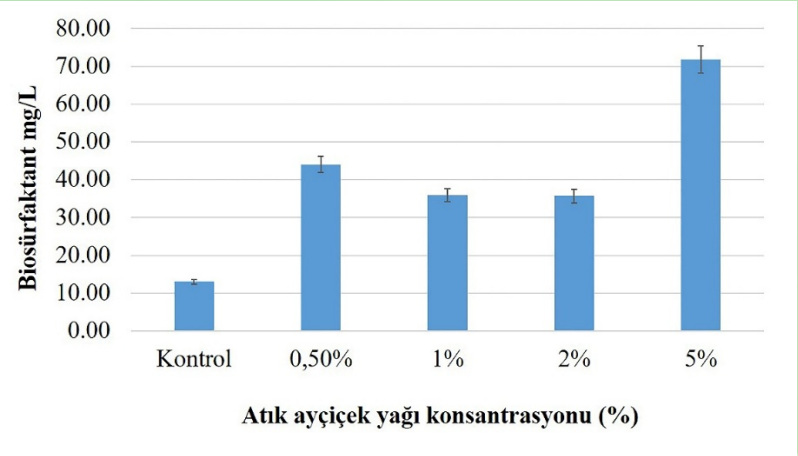
Şekil 3. Kanlı (%5 koyun kanı) agar üzerinde *A. caviae* LipT51'in hemolitik aktivitesi

Köpük testi sonuçlarına göre, Şekil 4'te gösterildiği gibi, zeytinyağı içeren numunelerde %56 oranında belirgin bir köpük oluşumu gözlemlenmiştir. Buna karşın, kontrol grubunda herhangi bir köpüklenme meydana gelmemiştir, bu da biyosürfaktan üretiminin varlığını destekleyen önemli bir bulgu olarak değerlendirilmiştir.



Şekil 4. %1'lik zeytinyağı içeren ortamda geliştirilen A. caviae süpernatatının köpük yüksekliği ölçümü

Biyosürfaktan miktarının belirlenmesinde kullanılan fenol-sülfürik asit yöntemi kapsamında, öncelikle standart bir L-ramnoz kalibrasyon eğrisi oluşturulmuştur. Daha sonra farklı miktarlarda (%0,5, 1, 2, ve 5) atık ayçiçek yağı içeren kültürlerdeki biyosürfaktan üretimleri karşılaştırılmıştır. Elde edilen standart eğriye göre yapılan hesaplamalara göre en yüksek biyosürfaktan üretimi Şekil 5'te görüldüğü üzere %5 atık ayçiçek yağı içeren kültürde elde edilmiştir.



Şekil 5. Farklı atık ayçiçek yağı konsantrasyonlarının biyosürfaktan üretimine etkisi

Gerçekleştiren analizler sonucunda *A. caviae* LipT51 suşunun biyosürfaktan ürettiği belirlenmiş ve yapılan testlerde yüzey aktif özellikler sergilediği görülmüştür. Parafilm M testi ve yağ yayma testi sonuçları biyosürfaktan varlığını doğrulamıştır. E24 emülsifikasyon indeksi, biyosürfaktanın emülsiyon oluşturma yeteneğini gösterirken, CTAB agar yöntemi ile glikolipid yapısındaki biyosürfaktanların varlığı tespit edilmiştir. Ayrıca, hemolitik aktivite testi pozitif sonuç vermiş ve biyosürfaktanın biyolojik aktivite gösterdiği belirlenmiştir. Köpüklenme testi sonuçları, biyosürfaktanın stabil köpük oluşturma kapasitesine sahip olduğunu ortaya koymuştur.

Bu bulgular, *A. caviae*'nin biyosürfaktan üretiminde etkili bir mikroorganizma olabileceğini ve biyoteknolojik uygulamalarda değerlendirilebileceğini göstermektedir. Özellikle çevresel biyoremediasyon, petrol kirliliğinin giderilmesi, tarım, gıda ve farmasötik endüstrilerinde biyolojik ajan olarak *A. caviae* kaynaklı biyosürfaktanın önemli bir potansiyel taşıdığı görülmektedir. Gelecekte yapılacak çalışmalarda, biyosürfaktan üretim verimliliğini artırmak, biyosürfaktanın kimyasal yapısını analiz etmek ve antimikrobiyal özelliklerini araştırmak üzerine olacaktır.

Teşekkür
Bu makale, Sümeyra Gürkök tarafından yönetilen "*Aeromonas caviae* ile Biyosürfaktan Üretimi ve Biyosürfaktanın Biyoteknolojik Kullanım Alanlarının Araştırılması" başlıklı yüksek lisans tezinden üretilmiştir. (Yüksek Lisans Tezi, Atatürk Üniversitesi, Erzurum/Türkiye, 2025). Bu araştırma Atatürk Üniversitesi Bilimsel Araştırma Projeleri Koordinasyon Birimi tarafından [FYL-2024-13379] numaralı proje kapsamında desteklenmiştir.

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Effect of stocking density on crablets nursing performance and assessment of growth comparison between wild-sourced and hatchery-sourced juvenile crabs

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Mud crab (*Scylla olivacea*) farming has gained popularity in Bangladesh but most farmers depend on wild juveniles for stock establishment. This dependency on wild sources for juvenile crabs is the key challenge for sustainable crab aquaculture. Hence, this study aims to assess the effect of stocking densities on the growth and survivability of crablets in the nursing pond and the growth comparison of wild and hatchery-sourced juvenile crabs in farming ponds. Thus, two separate experimental trials were conducted in a Randomized Complete Block design to determine the effective stocking density for crablets nursing and to compare the performance of wild and hatchery-sourced juveniles for aquaculture practices. Three different stocking densities (T1=1000 ind/decimal, T2=1500 ind/decimal, and T3= 2000 ind/decimal) were treated for seven weeks for the first experiment to compare the result of growth variables (body weight, carapace width, carapace length, and abdominal width) and survivability percentages. The study results showed that growth variables and survivability rate varied significantly ($p < 0.05$) in different weeks. However, at harvest, the highest body weight (27.33 ± 1.53 g), carapace width (55.17 ± 1.04 mm), carapace length (41.67 ± 0.58 mm) abdominal width (25.50 ± 0.50 mm), and survivability rate (58.10%) was observed at T1 stocking density. However, the highest survivability 60.67% was observed with hatchery-sourced juvenile crabs. The study explored that stocking density T1(1000 ind/decimal) is the most suitable density for crablets nursing in ponds, and the hatchery-sourced juvenile was better than that of wild-sourced juvenile for crab aquaculture practices.

Tabe 1. Effects of stocking densities on growth and survivability performance of crablets at harvest

Stocking Density	Body Weight (g)	Carapace Width (mm)	Carapace Length (mm)	Abdominal Width (mm)	Survivability (%)
T1	27.33 ± 1.53a	55.17 ± 1.04a	41.67 ± 0.58a	25.50 ± 0.50a	58.10 ± 3.35a
T2	24.63 ± 0.55b	51.67 ± 1.15b	38.67 ± 1.53b	24.67 ± 0.29b	49.24 ± 3.18b
T3	22.73 ± 0.23c	50.16 ± 2.02b	37.50 ± 0.50b	23.50 ± 0.87c	42.30 ± 3.13c

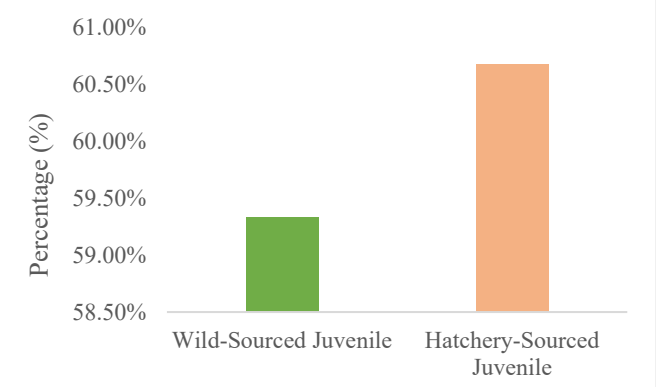


Fig.1 Survivability rate at harvest

ID: 473

Spatiotemporal Charactheristics in Climatic Extremes over Agricultural Lands in Türkiye

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Abstract

In recent years, heatwaves have developed into a phenomena that is growing more prevalent and severe on a worldwide scale. The issues of public health, agriculture, water supplies, and other environmental concerns are all significantly impacted by these heatwaves. The frequency, duration, and intensity of heatwaves have all been shown to have significantly increased, according to statistical data, both worldwide and regionally. Heat stress poses a threat to lives and livelihoods all across the world, particularly in the agricultural sector. By causing decreasing yields and a reduction in food quality, it exacerbates the water scarcity that already exists. Greater strain is being placed on water supplies as heatwaves exacerbate drought conditions, decrease the amount of water that is accessible, and raise the danger of wildfires. There are disruptions that occur in ecosystems, such as the loss of biodiversity and the deterioration of habitat systems. The frequency and duration of heatwaves in Mediterranean Basin are increasing. Across the country, there has been a notable increase in the number of heatwaves, and air temperatures have exceeded records in a number of different places. In a warming climate, it is projected that heatwaves would grow more frequent, stay longer, and extend across greater geographical regions. This is a cause for concern since it indicates that heatwaves will become more commonly occurring. In this study, using the most recent climate projections, the number of heatwave episodes that occurred across agricultural lands in Turkey as well as their length will be provided.

Key Words: *Climate Change, Extreme Events, Agriculture, Heat Stress.*

ID: 475

Effect on Germination of Mung Beans (*Vigna radiata* W.) Using Different Methods of Seed Priming

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Abstract

The productivity of mung beans (*Vigna radiata W.*) is harshly affected by patchy plant stand due to uneven seed germination. Seed priming can improve crop emergence and establishment, which are thought to be the primary causes of crop success. Thus,the study was to investigate the effect of priming agents on mung beans. The experiment was conducted under laboratory conditions at College of Natural Resource Management, Bardibas, Mahottari, Nepal. This research consisted of 6 treatments (T1; control, T2; 5% cow urine solution, T3; tap water, T4; 5% Moringa leaf extract solution, T5; 5% Neem leaf extract solution, and T6; 5% Aloe Vera sap solution) with 3 replication and laid out in complete randomized design (CRD). The seeds were soaked for 24 hours in priming solution and dried for 2 hours at room temperature before sowing. The germination diversity parameters (i.e. speed of germination, germination %, root length, shoot length, dry weight, seed vigour index 1, seed vigour index 2) were recorded and analyzed using Gen-Stat Ver.2015. The data revealed that all germination parameters of mung beans were highly affected by seed priming. The highest germination % (85.55%), dry weight (0.2180 gm), seed vigor index 1 (1942 cm) and seed vigor index 2 (1.865 gm) were observed in 5% Aloe Vera sap solution. Highest speed of germination (22.75 seeds/day) was observed in 5% cow urine solution followed by 5% Aloe Vera sap solution i.e. (22.43 seeds/day). The highest root length (5.04 cm) was recorded in 5% Neem leaf extract solution and shoot length (19 cm) in 5% Moringa leaf extract solution. Seed priming using aloe vera sap solution was found effective in mung beans to increase germination, crop establishment, seed and seedling vigor. In conclusion, this priming should be conducted in farmer's field condition for validation of the results.

Keywords: *Aloe vera, extracts, germination, leaf, neem, moringa, mung beans, seed priming, solution.*

ID: 476

The Impact of Carbon Emissions on the Agricultural Sector: A Comparative Analysis of Turkey and the European Union

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Abstract

This study examines the effects of agricultural value added, producer price index, fertilizer and energy consumption, and land surface temperature change on carbon emissions from the agricultural sector in Turkiye and the European Union (EU) countries. Using regression analysis, the determinants of agricultural carbon emissions were identified, and the differences between Turkiye and the EU were highlighted. The dataset covers the period from 2000 to 2022. The results reveal that in Turkiye, the agricultural producer price index, fertilizer use, and land surface temperature change have statistically significant positive effects on agricultural carbon emissions. In contrast, in the EU, the producer price index reduces emissions, while fertilizer use contributes to an increase. In both models, the positive impact of input use on emissions underscores the necessity of adopting sustainable production practices. The findings suggest that Turkiye should promote low-carbon agricultural approaches in alignment with the objectives of the European Green Deal.

Key Words: *Carbon emissions, Agricultural sector, EU–Turkiye comparison*

Karbon Emisyonlarının Tarım Sektörü Üzerine Etkileri: Türkiye-AB Karşılaştırması

Özet

Araştırmada, Türkiye ve Avrupa Birliği (AB) ülkelerinde tarımsal katma değer, üretici fiyat endeksi, gübre ve enerji kullanımı ile kara üzerindeki sıcaklık değişiminin; tarım sektöründen kaynaklanan karbon emisyonları üzerindeki etkileri incelenmiştir. Regresyon analizi ile karbon emisyonlarının belirleyicileri incelenerek, Türkiye ve AB arasındaki farklılıklar ortaya konulmuştur. Çalışmada değişkenlere ait veriler 2000-2022 dönemini kapsamaktadır. Türkiye'de tarımsal üretici fiyat endeksi, gübre kullanımı ve kara üzerindeki sıcaklık değişiminin tarımsal karbon emisyonlarını istatistiksel olarak anlamlı şekilde artırdığı tespit edilmiştir. Avrupa Birliği'nde ise tarımsal üretici fiyat endeksi karbon emisyonlarını azaltıcı yönde etkilerken, gübre kullanımı emisyonları artırıcı etki göstermiştir. Her iki modelde de tarımsal girdi kullanımının emisyonlar üzerindeki artırıcı etkisi, sürdürülebilir üretim tekniklerinin benimsenmesinin gerekliliğini ortaya koymaktadır. Elde edilen bulgular, Türkiye'nin Avrupa Yeşil Mutabakatı hedefleri doğrultusunda düşük karbonlu tarım uygulamalarını yaygınlaştırması gerektiğine işaret etmektedir.

Anahtar Kelimeler: *Karbon emisyonu, Tarım sektörü, AB-Türkiye karşılaştırması*

Giriş

İklim değişikliği ve çevresel bozulma, sadece Avrupa'nın değil, küresel ölçekte tüm dünyanın karşı karşıya olduğu en büyük tehditlerden biri haline gelmiştir (European Union EUR-Lex, 2025). Bu bağlamda, tarım sektöründe sera gazı emisyonlarının azaltılması, küresel ısınmayı 1,5 °C ile sınırlama hedefine ulaşmak açısından kritik öneme sahiptir (Van Hoof, 2023). Avrupa Birliği (AB), tarım sektörünün iklim değişikliğine etkisini azaltmak amacıyla uzun yıllardır Ortak Tarım Politikası (OTP) kapsamında çeşitli reformlar uygulamaktadır. Avrupa bütünleşmesinin ilk yıllarında tarımsal üretimi artırma ve tarımı yeniden yapılandırma amacıyla başlatılan OTP, günümüzde AB'nin en uzun soluklu politikası haline gelmiş; çiftçilere, kırsal alanlara ve tarım-gıda sistemine ekonomik, sosyal ve çevresel açılardan destek sağlamaya devam etmiştir. 2021–2027 döneminde AB bütçesinin %31'i OTP'ye ayrılmıştır (European Union EUR-Lex, 2025). 2023 yılı itibarıyla yürürlüğe giren OTP'nin altıncı büyük reformu, sürdürülebilir tarımı desteklemeyi, küçük ölçekli çiftliklere hedefli destek sunmayı ve üye devletlere yerel koşullara uygun esneklik tanımayı amaçlamaktadır. Bu reformla birlikte, AB vatandaşları için istikrarlı, güvenli ve sağlıklı bir gıda arzı sağlanması hedeflenmiş; daha adil, daha yeşil ve performansa dayalı bir OTP oluşturulmuştur. Tarım ve kırsal alanlar, Avrupa Yeşil Mutabakatı'nın temel bileşenleri arasında yer almakta; OTP, çiftlikten çatala ve biyolojik çeşitlilik stratejilerinin hedeflerine ulaşmada anahtar bir araç niteliği

taşımaktadır (European Union EUR-Lex, 2025). Benzer şekilde, Türkiye'de iklim değişikliğiyle mücadelede iddialı hedefler belirlemiştir. 2012 yılını baz alarak güncellediği Birinci Ulusal Katkı Beyanı'nda Türkiye, 2030 yılına kadar sera gazı emisyonlarını %41 oranında azaltmayı taahhüt etmiştir. Bu hedef, 2030 yılı itibarıyla emisyonların 695 Mt CO2 eşdeğeri seviyesinde olmasını öngörmektedir. Türkiye'nin beyanı, azaltım ve uyum eylemlerini içeren kapsamlı bir planı ortaya koymakta; emisyonların en geç 2038 yılında zirve yapması ve 2053 itibarıyla net sıfır seviyesine ulaşılması hedeflenmektedir (Türkiye Cumhuriyeti Güncellenmiş Birinci Ulusal Katkı Beyanı, 2023).

Tarım sektöründe Türkiye, 2030 yılına kadar karbon emisyonlarını azaltmak için çeşitli stratejiler benimsemiştir. Bu kapsamda, hayvan yemi rasyonlarının düzenlenmesi, biyogaz tesislerinin etkin kullanımı ve gübre yönetiminin iyileştirilmesiyle metan emisyonlarının azaltılması; bitkisel üretimde ise azotlu gübre kullanımının azaltılması, baklagil ekiminin teşvik edilmesi ve optimum gübre kullanımının sağlanması hedeflenmektedir. Ayrıca, pirinç üretiminde yüzey altı sulama sistemlerinin geliştirilmesi, tarımsal biyokütleden enerji üretiminin artırılması ve toprak koruma uygulamalarının yaygınlaştırılması planlanmaktadır. Bu önlemlerin yanı sıra çiftçilere sürdürülebilir tarım uygulamaları konusunda eğitim verilmesi ve su yönetimi ile tahsis planlarının geliştirilmesi yoluyla tarım sektörünün iklim değişikliğine uyumu desteklenecektir (Türkiye Cumhuriyeti Güncellenmiş Birinci Ulusal Katkı Beyanı, 2023).

AB'nin 2023–2027 OTP dönemi hedefleri arasında, sera gazı emisyonlarının azaltılması, karbon tutulmasının artırılması ve sürdürülebilir enerjinin teşvik edilmesi yer almakta; bu hedefler aracılığıyla hem iklim değişikliğinin hafifletilmesine hem de uyum sağlanmasına katkı sunulması amaçlanmaktadır (European Commission, 2025). Benzer şekilde Türkiye de tarım sektörüne yönelik sera gazı azaltımını, kapsamlı politikalarıyla desteklemektedir. Ancak, AB OTP aracılığıyla daha yapısal ve merkezi finansman mekanizmaları yürütürken, Türkiye'nin uygulamaları daha çok sektörel projeler etrafında şekillenmektedir.

Türkiye ve Avrupa Birliği (AB) ülkelerinde tarım sektörüne ilişkin ekonomik göstergeler ile çevresel değişkenlerin tarımsal karbon emisyonları üzerindeki etkilerini ortaya koymak çalışmanın amacıdır.

Materyal ve Yöntem

Çalışmanın ana materyalini ikincil veriler oluşturmaktadır. Araştırmada kullanılan Türkiye Avrupa Birliği (27 ülke) ülkelerine ait 2000-2022 yılları arasında Birleşmiş Milletler Gıda ve Tarım Örgütü (FAO) tarafından sağlanan veriler kullanılmıştır. Çoklu regresyon analizinde kapsamında kullanılan değişkenler şu şekildedir:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon$$

Y : Tarımsal karbon emisyonu (CO2-eq, kt)
β_0: Sabit terim
X_1: Tarımsal katma değer (milyon USD)
X_2: Tarımsal üretici fiyat endeksi (2014-2016=100)
X_3: Tarımsal girdi kullanımı (NPK gübre tüketimi, ton)
X_4: Tarımsal enerji kullanımı (TJ)
X_5: Kara üzerindeki sıcaklık değişimi (°C)
ε: Hata terimi.

Karbon yoğunluğu (kg CO_2-eq / milyon USD), tarımsal katma değer başına düşen sera gazı emisyonlarını hesaplamak için kullanılmıştır. Karbon yoğunluğu şu formülle hesaplanmıştır:

$$\text{KY} = \frac{E}{TKD}$$

KY = Karbon yoğunluğu (kg CO_2-eq / milyon USD),
E = Toplam tarımsal karbon emisyonları (kiloton CO_2-eq),
TKD = Tarımsal Katma Değer (milyon USD, sabit fiyatlarla).

Bu yöntemle hesaplanan karbon yoğunluğu, tarım sektörünün ekonomik çıktısı başına ürettiği sera gazı miktarını göstererek Türkiye ve Avrupa Birliği (AB) arasındaki çevresel etkinliği karşılaştırmaya olanak tanımaktadır.

Bulgular ve Tartışma

Araştırma verileri ile tarımsal karbon emisyonlarını etkileyen faktörler regresyon analizi ile açıklanmaya çalışılmıştır. Modelde bağımlı değişken olarak tarımsal karbon emisyonu Y ($CO_{2\text{-eq}}$, kt); bağımsız değişkenler olarak ise tarımsal katma değer X_1 (milyon USD), Tarımsal üretici fiyat endeksi X_2 (2014-2016=100), tarımsal girdi kullanımı X_3 (NPK gübre tüketimi, ton), Tarımsal enerji kullanımı X_4 (TJ), kara üzerindeki sıcaklık değişimi X_5 (°C) alınmıştır. Regresyon analizi sonucunda hesaplanan modeller şu şekildedir:

Türkiye için;

$$Y = 16233{,}938 - 0{,}044X_1 + 29{,}766X_2 + 0{,}011X_3 - 0{,}017X_4 + 3160{,}380X_5 + \varepsilon$$

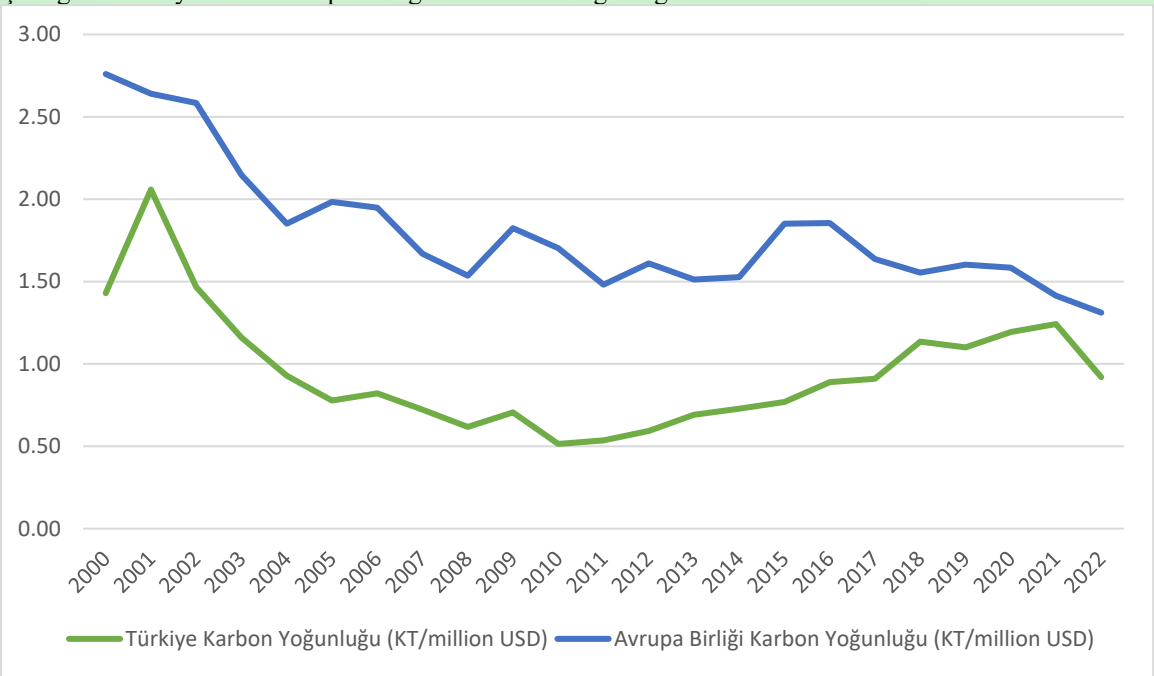
Avrupa Birliği için;

$$Y = 380207{,}455 - 0{,}095X_1 - 313{,}416X_2 + 0{,}002X_3 + 0{,}970X_4 + 963{,}935X_5 + \varepsilon$$

Türkiye'de ve Avrupa Birliğinde karbon yoğunluğu Çizelge 1'de verilmiştir. Türkiye'de tarımsal karbon emisyonlarının yıllık ortalaması 42.596,6 kt, AB'de ise 410.847 kt olarak hesaplanmıştır. Türkiye'nin tarımsal

karbon yoğunluğu 2000 yılında 1,43 kt/milyon USD iken 2022'de 0,91 kt/milyon USD'ye gerilemiştir. AB'de ise bu değer 2,76 kt/milyon USD'den 1,31 kt/milyon USD'ye düşmüştür (Çizelge 1).

Çizelge 1. Türkiye'de ve Avrupa Birliğinde Karbon Yoğunluğu



Türkiye için hesaplanan regresyon analiz sonuçları Tablo 1'de sunulmuştur. Modelin açıklayıcılığı oldukça yüksektir ($R^2 = 0,843$), bu da bağımsız değişkenlerin karbon emisyonlarındaki değişimi büyük ölçüde açıkladığını göstermektedir. Modelin genel olarak anlamlılığını gösteren F-testi anlamlıdır ($p<0,001$) ve denklemde otokorelasyon problemi yoktur (Durbin-Watson=1,755). Tarımsal üretici fiyat endeksi ($p<0,001$), tarımsal girdi kullanımı ($p<0,001$) ve kara üzerindeki sıcaklık ($p<0,05$) arttıkça tarımdan kaynaklanan karbon emisyonlarında artış olduğu tespit edilmiştir. Modelden elde edilen esneklik katsayıları tarımsal girdilerin ve sıcaklık değişimlerinin karbon emisyonlarına duyarlılığını ortaya koymakta; özellikle tarımsal girdi kullanımındaki %1'lik artışın emisyonları %0,51 oranında artırması, sürdürülebilir üretim tekniklerinin önemini vurgulamaktadır. Benzer şekilde, sıcaklık artışına duyarlılık, iklim değişikliğinin etkisini gözler önüne sermekte, tarım sektörünün iklim kırılganlığını pekiştirmektedir. Bu nedenle, düşük karbonlu tarım uygulamalarının yaygınlaştırılması ve iklim dostu üretim yöntemlerinin teşvik edilmesi gereklidir. (Tablo 1).

Avrupa Yeşil Mutabakatının Türkiye'deki tarımsal karbon emisyonları üzerinde önemli bir etkisinin olduğu sonucuna varılmıştır (Taneja ve Özen, 2023). Türkiye'de tarımda %1'lik bir artış CO_2 emisyonlarını %1,516 oranına artırdığı tespit edilmiştir. Bu bulgu, sektördeki fosil yakıt kullanımının emisyonlar üzeridenki belirleyici etkisi olduğu anlamına gelmektedir (Yurtkuran, 2021). Avrupa ülkelerinde yapılan bir çalışmada özellikle Hollanda, Belçika ve Lüksemburg gibi ülkelerde azotlu gübre kullanımının artmasının, emisyon yoğunluğunu üzerinde %100'ü aşan etkiler yarattığı vurgulanmıştır (Robaina-Alves ve Mountinho, 2014). Avrupa OECD ülkelerinde yapılan bir çalışmada yine benzer bir sonuç ile gübre kullanımının karbon ayak izi üzerinde arttırıcı etkileri olduğu belirlenmiştir (Haller, 2022). Bu bulgular, Türkiye'de gübre kullanımının CO_2 emisyonlarını artırıcı etkisine ilişkin bu çalışmanın sonuçlarıyla örtüşmektedir. E7 ülkelerinde yapılan bir çalışmada, tarımsal katma değerdeki artışın uzun vadede CO_2 emisyonlarını arttırdığı tespit edilmiştir (Aydoğan ve Vardar, 2020). Ancak Türkiye'de CO_2 emisyonunda yaşanacak değişikler, tarımsal GSYİH üzerinde anlamlı ve negatif bir etkide bulunarak, uzun dönemde tarım verimi ve tarımsal ürünlerin kalitesini düşürmektedir (Bayraç ve Doğan, 2016). Bu bulgular, tarım ve çevre ilişkisini çift yönlü değerlendiren bütüncül politikalara olan ihtiyacı göstermektedir. Yine Türkiye'de tarımsal ihracatın uzun vadede çevresel bozulmayı önemli ölçüde azalttığı tespit edilmiştir (Turan, 2025). Türkiye'nin Avrupa Birliğine ihracatından kaynaklanan emisyonların, Avrupa Birliğinin Türkiye'ye ihracatından kaynaklanan sera gazı emisyonlarından fazla olduğu tespit edilmiştir (Tunç vd., 2022). Türkiye'de tarım sektörü iklimsel etkilerden yüksek düzeyde etkilenmektedir. Bu durumda tarım sektörünün iklim değişikliğine karşı kırılgan olduğunu göstermektedir (Kılıç, 2022). Türkiye'de tarımsal verimlilikte meydana gelecek %1'lik artış karbondioksit emisyonlarında %0,12 oranında azalmaya neden olacağı tespit edilmiştir (Raihan ve Tuspekova, 2022). Cortignani ve Coderoni (2022) tarafından İtalya tarım sektörü üzerine yapılan çalışmada, çevresel hedeflerin uygulanmasının çiftliklerin ekonomik performansını olumsuz etkileyebileceği; ancak sera gazı emisyonlarının önemli ölçüde azaltılabileceği tespit edilmiştir. Türkiye'de de gübre kullanımı ve sıcaklık artışının emisyonları artırıcı etkisi, benzer politika senaryolarının ekonomik ve çevresel etkiler

bakımından değerlendirilmesini gerekli kılmaktadır. Bu bağlamda, Türkiye'nin Avrupa Birliğine uyum sağlayabilmesi ve tarım sektöründe karbon emisyonlarını azaltabilmesi için bütüncül önlemler alması ve stratejik politikalar geliştirmesi gerekmektedir. Özellikle gübre kullanımı ve tarımsal girdi verimliliği, öncelikli müdahale alanları olmalıdır. Ayrıca fiyat mekanizmalarının, çevre dostu üretim yöntemlerini teşvik edecek şekilde yeniden yapılandırılması büyük önem taşımaktadır.

Tablo 1. Türkiye için Regresyon analiz sonuçları

Değişkenler	Katsayı	Standart hata	p	t-değerleri	Esneklik
Sabit	16233,938	9604,437	0,109	1,690	-
X_1	-0,044	0,066	0,511	-0,671	-0,082
X_2	29,766	7,800	0,001***	3,816	0,427
X_3	0,011	0,003	0,001***	3,990	0,510
X_4	-0,017	0,041	0,681	-0,418	-0,053
X_5	3160,380	1288,398	0,025**	2,453	0,263
F testi	18,257		0,000***		
R^2	0,843				
Durbin-Watson	1,755				

*, ** ve *** ilgili değişkenlerin bağımlı değişken üzerinde etkisinin sırasıyla %10, %5, %1 ihtimal düzeyinde istatistiki açıdan önemli olduğunu ifade etmektedir.

Avrupa Birliği için hesaplanan regresyon analiz sonuçları Tablo 2'de verilmiştir. Modelin açıklayıcılığı Türkiye'den daha yüksektir (R^2 = 0,901). Bağımsız değişkenler, tarımsal karbon emisyonlarındaki değişimin %90,1'ini açıklıyor. Modelin genel olarak anlamlılığını gösteren F-testi anlamlıdır ($p<0,001$) ve denklemde otokorelasyon problemi yoktur (Durbin-Watson=1,755). Tarımsal üretici fiyat endeksi ($p<0,05$) arttıkça karbon emisyonlarını azaltırken, tarımsal girdi kullanımı ($p<0,05$) arttıkça tarımdan kaynaklanan karbon emisyonlarında artış olduğu tespit edilmiştir. Modelde elde edilen esneklik katsayıları, Avrupa tarımının emisyonlara olan tepkisini ortaya koymaktadır. Tarımsal üretici fiyat endeksindeki %1'lik artışın karbon emisyonlarını %0,42 oranında azaltması, piyasa fiyatlarının çevresel etkileri şekillendirmede önemli bir rol oynayabileceğini göstermektedir. Buna karşılık, tarımsal girdi kullanımındaki %1'lik artışın emisyonları %0,23 oranında artırması, Avrupa tarımında da sürdürülebilir girdi kullanımının gerekliliğini ortaya koymaktadır (Tablo 2). AB'nin tarımda uyguladığı karbon ayak izi temelli destek sistemleri ve düşük emisyonlu üretim tekniklerine sağladığı finansal teşvikler, çevresel hedeflere ulaşmada önemli bir araç olarak öne çıkmaktadır. Türkiye'nin de yenilenebilir enerji kaynaklarının tarımsal üretime entegrasyonunu hızlandırması ve çiftlik bazlı enerji dönüşümünü desteklemesi gerekmektedir.

Avrupa ülkelerinde tarımsal gayrisafi katma değerin karbon emisyonları üzerinde farklı yönlerde etkiler oluşturduğu gösterilmiştir. Avrupa ülkelerinde özellikle Almanya, Fransa ve Birleşik Krallık gibi ülkelerde 1990-2016 döneminde tarımsal karbon emisyonlarında anlamlı azalmalar gözlemlenmiştir (Mohammed vd., 2020). Kuzey Avrupa ülkelerinde tarımın emisyonları artırdığı, Güney Avrupa ülkelerinde ise azaltıcı yönde etkide bulunduğu tespit edilmiştir (Sibgh ve Dhiman, 2022). Bu çalışmadan elde dilen AB bulguları, özellikle Güney Avrupa'daki negatif ilişkiyle örtüşmektedir. Bu durum, daha sürdürülebilir tarım uygulamalarının yaygın olduğu bölgelerde, tarımsal üretimin çevre için daha zararlı olabileceğini göstermektedir. Avrupa Birliği 2030 yılına kadar, yalnızca tarımdan kaynaklanan sera gazı emisyonlarını azaltmakla kalmayıp aynı zamanda karbon sekastarsyonunu arttıran, tarımsal üretimin dayanıklılığını arttıran, kırsal alandaki biyolojik çeşitliliği iyileştiren ve büyüyen dünya nüfusuna besleyici ve sağlıklı gıda sağlamaya katkıda bulunan düzenleyici araçlara sahip olmaldır (Verschuuren, 2022). CO_2 emisyonlarında bazı dalgalanmalara rağmen, Avrupa Birliği genelinde tarım sektöründe karbon nötrlüğüne ulaşma stratejileri izlenmelidir (Harsányi vd., 2021). Bu stratejiler arasında emisyon yoğunluğunu iyileştirmede tarımsal üretimi desteklemeye devam etmelidir (Bajan vd., 2022). Bu bağlamda, hem çevresel hedeflere ulaşmak hem de üretim kapasitesini korumak amacıyla, düşük emisyonlu üretim yöntemleri teşvik edilmekte, üretici gelirleri ise çeşitli destek mekanizmaları ile güvence altına alınmaktadır.

Tablo 2. Avrupa Birliği için regresyon analiz sonuçları

Değişkenler	Katsayı	Standart hata	p	t-değerleri	Esneklik
Sabit	380207.455	40528,640	0.000***	9,381	-
X_1	-0.095	0,058	0.123	1,625	-0.238
X_2	-313.416	116,951	0.016**	2,680	-0.419
X_3	0.002	0,001	0.042**	2,204	0.235
X_4	0.970	3229,473	0.792	0,267	0,028
X_5	863.835	0,620	0.136	1,563	0,204
F testi	30.929		0.000		
R^2	0.901				
Durbin-Watson	1.225				

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Okul Çağı Çocuklarında Ambalajlı Gıda Tüketim Alışkanlıklarının Belirlenmesi Obezite İle İlişkisinin İncelenmesi

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Özet

Amaç: Hızla değişen modern dünyada, tüketiminin hızlı, taşınmasının kolay olması ve daha ekonomik olması sebebiyle bireylerin paketlenmiş gıda ve fast food ürün tüketimleri artmıştır. Bu gruptaki besinlerin enerji ve yağ içeriği geleneksel gıdalara oranla oldukça yüksektir. Sağlıklı beslenme alışkanlıklarının değişmesiyle beraber yetersiz fiziksel aktivite nedeniyle dünya genelinde obezite oranları hızla artmaktadır. Çocukluk döneminde kazanılan beslenme alışkanlıkları obezite ve beraberinde getirebileceği hastalıkları önleme noktasında kritik öneme sahiptir. Bu çalışma kapsamında, öğrencilerin beslenme davranışları ve paketlenmiş gıda tüketim sıklığının kilo kontrolü ve obezite üzerindeki etkisinin incelenmesi amaçlanmıştır.
Yöntem: İstanbul ili Güngören ilçesinde yer alan ilkokul ve ortaokullarda eğitim gören 7-14 yaş arasındaki gönüllü katılımcılar çalışmaya dahil edilmiştir. Araştırmacılar tarafından hazırlanan ve sosyo-demografik özellikleri ve beslenme alışkanlıklarını değerlendiren anket formu, tüm katılımcılara uygulanmıştır. Çalışmada 98 çocukla yapılan anket ile sağlık durumu, yeme alışkanlıkları, besin tüketimi verileri toplanmış ve antropometrik ölçümler yapılmıştır.
Bulgular: Araştırma bulgularına göre, çocukların Vücut Kitle İndeksi (VKİ) değerlerine göre beslenme alışkanlıkları arasında anlamlı ilişkiler bulunmuştur. Evde yemek yiyen çocuklar ile okul kantininde yemek yiyen çocuklar arasındaki ilişki dikkate alındığında, evde yemek yiyen çocukların VKİ değerleri anlamlı olarak daha düşük bulunmuştur ($p<0,05$). Paketlenmiş gıda tüketimi ile BMI arasındaki ilişki de anlamlı bulunmuştur. Haftada bir veya daha fazla paketlenmiş gıda tüketen çocukların VKİ değerlerinde, daha az tüketenlere göre istatistiksel olarak farklılıklar gözlemlenmiştir ($p<0,05$). Ayrıca, annenin eğitim düzeyi ile çocuğun paketlenmiş gıda tüketimi arasında da anlamlı bir ilişki bulunmuştur ($p<0,05$).
Sonuçlar: Okul çağı dönemi tüm hayat boyu sürecek ve sağlığı etkileyen davranışların kazanıldığı bir dönemdir. Bu yaşlardaki çocuklar günün büyük bir kısmını okulda geçirmekte ve okulda kantin/yemekhane hizmetinden yararlanmaktadırlar. Toplum sağlığı açısından okul çağı çocuklarının sağlıklı besinlere ulaşımının sağlanması ve sağlıklı beslenme alışkanlıklarının kazandırılması başta çocukluk çağı obezitesinin önlenmesi olmak üzere birçok olumlu etkilere sahiptir. Bu gruptaki çocuklara verilecek olan beslenme eğitimleri ve okul diyetisyenliği çalışmaları ile okul çağı çocuklarına büyük faydalar sağlanabilir.

Anahtar Kelimeler: Obezite, Beslenme, Paketli Gıda, Beslenme Durumu

Determination Of Packaged Food Consumption Habits In School Age Children And Examination Of Their Relationship With Obesity

Abstract

Purpose: In the rapidly changing modern world, individuals have increased their consumption of packaged and fast food products due to their convenience, ease of transportation, and relatively economical nature. The energy and fat content of foods in this group are considerably higher than those of traditional foods. Along with the shift in eating habits, obesity rates are rising rapidly worldwide due to insufficient physical activity. Eating habits acquired during childhood are critical in preventing obesity and the associated diseases. The aim of this study is to examine the effects of students' eating behaviors and the frequency of packaged food consumption on weight control and obesity.
Method: Volunteer participants between the ages of 7 and 14, studying in primary and secondary schools in the Güngören district of Istanbul, were included in the study. A questionnaire prepared by the researchers, which assessed socio-demographic characteristics and eating habits, was administered to all participants. In the study, health status, eating habits, and food consumption data were collected through a questionnaire administered to 98 children, and anthropometric measurements were taken.
Findings: The research findings revealed significant relationships between children's eating habits and their Body Mass Index (BMI) values. The BMI values of children who ate at home were significantly lower than those who ate in the school cafeteria ($p<0.05$). Additionally, a significant relationship was found between packaged food consumption and BMI. Statistical differences were observed in the BMI values of children who consumed packaged food once or more per week compared to those who consumed it less frequently ($p<0.05$). Moreover, a significant relationship was found between the mother's education level and the child's packaged food consumption ($p<0.05$).
Results: The school-age period is crucial for the development of lifelong behaviors that affect health. Children in this age group spend most of their day at school and utilize school canteen/cafeteria services. In terms of public health, ensuring that school-age children have access to healthy foods and promoting healthy eating habits can have numerous positive effects, most notably in preventing childhood obesity. Nutrition education and school dietitian interventions for children in this age group can provide significant benefits for their health.

Key Words: *Obesity, Nutrition, Packaged Food, Nutritional Status*

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The Current Situation and Future of Beekeeping in Düzce

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Abstract

Düzce is one of the significant provinces for beekeeping in the Western Black Sea region of Türkiye due to its geographical location, climate, and floral diversity. The province has gained prominence in the apiculture sector through the registration of the Yığılca honey bee ecotype and the patenting of its chestnut honey. The Yığılca ecotype, which is endemic to the Yığılca district, is a highly specialized subspecies in terms of morphological, genetic, and physiological traits, and is known for its high productivity. Following the official registration of the Düzce-Yığılca ecotype by the Breed Registration Commission of the Ministry of Agriculture and Forestry, nine queen bee production enterprises were established in the district.

Currently, there are 713 registered beekeeping enterprises and 59,911 hives listed in the Beekeeping Registration System in Düzce. The province produces monofloral chestnut honey, Rhododendron honey, and polyfloral flower honey. However, beekeepers in Düzce primarily focus on monofloral chestnut (*Castanea*) and Rhododendron honey production. Based on a ten-year average, Düzce ranks 54th in Türkiye with an annual production of 551 tons of honey. The average annual production of beeswax is 22.117 tons, ranking 46th nationally. In recent years, increased attention has been paid to the production of high value-added bee products such as royal jelly and propolis, although these products are not yet reflected in official statistics.

Although Düzce does not rank among the top provinces in Türkiye in terms of total honey production, its unique flora and fauna, patented chestnut honey, and the Yığılca ecotype render it strategically important for the future of beekeeping in the country. The aim of this study is to examine the most recent data on beekeeping in Düzce including the production volumes of various bee products and colony management practices in order to develop a strategic roadmap and plan for the sustainable development of beekeeping in the province.

Keywords: *Beekeeping, Apis mellifera, raw material production, Düzce Province*

Düzce'de Arıcılığın Mevcut Durumu ve Geleceği

Özet

Düzce, Türkiye'nin Batı Karadeniz bölgesinde yer alan coğrafik konumu, iklimi ve floral yapısı bakımından arıcılık açısından önemli illerimizden biridir. Düzce arıcılık sektöründe tescilli Yığılca bal arısı ve patentli kestane balıyla ön plana çıkmıştır. Düzce'nin Yığılca ilçesine endemik olan Yığılca ekotipi morfolojik, genetik ve fizyolojik bakımlardan özelleşmiş, davranış ve performans bakımından yüksek verimli bir ekotiptir. Düzce Yığılca ekotipi Tarım Orman Bakanlığı ırk tescil komisyonu tarafından tescillendikten sonra İlçede 9 adet ana arı üretim işletmesi kurulmuştur. Düzce genelinde arıcılık kayıt sistemine kayıtlı 713 adet arıcılık işletmesi ve 59.911 adet arılı kovan bulunmaktadır. İlde monofloral kestane balı, ormangülü ve polifloral çiçek balı üretilmektedir. Ancak Düzce ilinde arıcılar monofloral kestane (*Castane*) ve orman gülü (*Rhododendron*) balı üretimi üzerinde yoğunlaşmıştır. Düzce'de on yıllık ortalamaya göre 551 ton/yıl bal üretimi yapılmakta olup Türkiye genelinde 54. Sırada yer almaktadır. Balmumu üretimi ise ortalama 22.117 ton olup 46. Sırada bulunmaktadır. Son dönemlerde arı sütü ve propolis gibi bal dışındaki katma değeri yüksek ürünlerin üretimine de ağırlık verilmiştir. Ancak bu üretim tipleri istatistiklere yansıtılmamıştır. Düzce ili arıcılık faaliyeti bakımından Türkiye'de üst sıralarda olmasada, yerel flora ve fauna kaynakları, patentli kestane balı ve eşsiz Yığılca ekotipi nedeniyle Düzce ili arıcılık faaliyetleri nedeniyle Türkiye için son derece önemlidir.

Bu çalışmanın amacı Düzce'de son yıllık süreçte arıcılığın durumu, arı ürünleri üretimi ve üretim miktarı, koloni bakım yönetiminde yapılan uygulamalara ilişkin verileri inceleyerek Düzce arıcılığı için gelecek planlamaları yapmak ve yol haritası oluşturmaktır.

Anahtar Kelimeler: Arıcılık, Apis mellifera, ham madde üretimi, Düzce

Introduction

Honey bees (*Apis mellifera*) hold significant importance due to their production of various substances with high pharmacological and nutritional value. These substances include eight different bee products: honey, pollen, beeswax, propolis, royal jelly, apilarnil, bee bread (perga), and bee venom. In addition to being used as nutritional supplements, these products also have widespread applications in the pharmaceutical and cosmetic industries. However, the role of honey bees in pollination which enhances both the quantitative and qualitative aspects of crop yields is considered even more vital than the products themselves (Free, 1993). Honey bees are responsible for approximately 85% of all insect-mediated pollination, positioning them as key contributors to ecological balance. Therefore, their role as primary pollinators is essential for environmental sustainability.

In contemporary agricultural practices, the intensive use of chemicals particularly pesticides has led to a significant decline in the populations of wild pollinators. As a result, honey bees have emerged as the sole effective pollinators capable of filling this ecological gap. One-third of the human diet is derived, either directly or indirectly, from plants that require bee pollination. For this reason, honey bee colonies are critical during vegetation periods to ensure sufficient pollination (Delaplane and Mayer, 2000).

Although wild bees and other insects also play a role in natural pollination, honey bees are considered the most effective due to their large colony sizes, ease of transportation, and manageability. Most of pollination activities in nature is carried out by honey bees, and the economic value of this service is estimated to be approximately 15 times greater than the value of honey. A mutually beneficial relationship exists between forests and bees: As the world's most important pollinating insects, bees also contribute to the propagation of herbaceous and woody plants that protect the soil, thereby helping to prevent erosion particularly critical in a country like Türkiye (Özbek, 2002). Beekeeping is a sector that must be supported and sustained due to its contributions to biodiversity conservation, sustainable food security, and the Turkish economy (Kekeçoğlu et al., 2014). Approximately 40,000 families in Türkiye rely on beekeeping for their livelihoods. There are 72,000 registered beekeepers, and it is estimated that 300,000 individuals are financially dependent on this sector (Table 1). Both local and national surveys indicate that the average age of beekeepers is around 49 years (Kekeçoğlu et al., 2007; Kekeçoğlu et al., 2013).

According to 2020 data from the Food and Agriculture Organization (FAO), the global number of bee colonies has reached 90.1 million. India ranks first with 13 million colonies and a 13.6% share, followed by China with 9 million colonies (10.1%), and Türkiye ranks third with 8 million colonies, corresponding to a 9.0% share. In terms of total honey production, China is the global leader with 446,900 tons, producing 49.39 kg per colony. Türkiye ranks second with 114,113 tons but falls far behind in colony productivity, with a yield of 14.36 kg per hive.

Table 1. Beekeeping data for 2023 by some country (FAO, 2023)

Rank	Country	Number of Colonies (units)	Total Honey Production (tons)	Honey Yield (kg/hive)
1	China	9,492,353	472,221.14	49.39
2	Türkiye	9,224,881	114,886.43	14.36
3	Ethiopia	6,794,876	84,591.00	8.31
4	Iran	7,358,044	80,389.00	11.75
5	Argentina	3,013,042	73,395.30	26.31
6	India	12,663,817	70,850.20	5.17
7	Russia	2,743,100	64,511.00	20.43
8	Brazil	1,026,934	64,189.00	41.62
9	United States	2,509,000	62,855.00	24.65
10	Mexico	2,201,329	58,033.20	29.58
11	Tanzania	3,080,237	31,613.10	10.13
12	South Korea	2,128,266	29,467.80	12.34
13	Angola	1,192,639	23,458.90	20.29
14	Kenya	1,676,583	17,151.00	13.38
15	Central African Republic	1,675,246	16,714.00	9.64
16	Serbia	1,103,300	11,346.00	12.50

When the average figures of the past four years in Türkiye are examined, the average number of beehives is 7,343,182; the number of beekeeping enterprises is 82,139; annual honey production is approximately 103,018 tons; and annual beeswax production is around 4,372 tons. In addition to honey, beeswax production on a global scale totals 66,099 tons. India ranks first with 25,691 tons of beeswax production, while Türkiye ranks fifth with 4,737 tons (TÜİK, 2021). Furthermore, although not officially recorded in national statistics, it is estimated that Türkiye produces approximately 100 tons of propolis, 3 tons of royal jelly, 150 tons of pollen, 10 tons of bee bread (perga), and 100 kilograms of bee venom annually.

As a branch of agricultural production, beekeeping contributes approximately 160 trillion Turkish Liras directly to the national economy through the production of honey and beeswax. When the contribution of pollination is

considered which is estimated to be at least 10 to 15 times greater than that of honey and beeswax production the total economic contribution of beekeeping to the Turkish economy rises to approximately 1.6 to 2.4 quadrillion Turkish Liras. In addition, beekeeping serves as a source of employment for nearly 150,000 individuals, the majority of whom live in rural areas and lack access to sufficient farmland. This further underscores the significance of beekeeping for the national economy.

Beekeeping in Düzce

When considering honey production at the provincial level in Türkiye, Ordu ranks first with 17,057 tons, followed by Muğla (14,688 tons) and Adana (11,077 tons) (FAO, 2020). Düzce ranks 54th in terms of total honey production. According to research, the active beekeeping season in Düzce spans June, July, and August (Albayrak and Bayır, 2019). The high number of rainy days and short beekeeping season constitute disadvantages for beekeeping in the province. On the other hand, the extensive forested areas, the abundance of chestnut and *Rhododendron* plants, and rich plant biodiversity provide significant advantages. Approximately 700 plant species, 10% of which are endemic, are found within Düzce's borders (Aksoy et al., 2010). One-third of the province is covered by forests. According to the General Directorate of Forestry, Türkiye has 262,045 hectares of chestnut forests, with approximately 15,767 hectares located in Düzce.

Two harvests take place annually in Düzce: *Rhododendron* honey is harvested in June, followed by chestnut honey in July. Both are classified as monofloral honeys. Chestnut and *Rhododendron* honeys, which are sold at higher prices and are valued for their apitherapeutic properties, form the primary production profile of Düzce. Scientific studies have confirmed the therapeutic properties of chestnut and wildflower honeys produced in the region, increasing the added value of local honey and propolis. Research indicates that the chestnut honey and propolis from Yığılca district exhibit antibacterial activity comparable to various antibiotics (Kekeçoğlu et al., 2021; 2022).

More importantly, the most significant factor elevating Düzce's beekeeping profile and increasing its international visibility is the presence of the Yığılca honey bee ecotype (Kekeçoğlu, 2010; Gültekin, 2019; Kekeçoğlu, 2021). Unique to Yığılca district, this ecotype produces up to three times more honey than other native bee subspecies in Türkiye and shows superior spring development and overwintering abilities compared to Anatolian and Caucasian races. As a result of research conducted by the Beekeeping Research, Development and Application Center (DAGEM) at Düzce University, established in 2009, the Yığılca bee was granted legal protection by the Ministry of Agriculture and Forestry on September 14, 2017 (official letter no: 73291108-12502.04-E 2223544). On May 22, 2022, the ecotype was officially registered by the National Commission for the Registration of Native Animal Breeds. Scientific data generated by DAGEM played a pivotal role in this registration process (Kekeçoğlu, 2010; 2018; Kekeçoğlu et al., 2021; Bir and Kekeçoğlu, 2021).

DAGEM's work has not only contributed to the recognition of the Yığılca bee but has also increased the value of local bee products. The center has been instrumental in transforming bee products into high value-added goods, facilitating their commercialization and branding. Products like propolis and bee venom, which had not been previously produced in Düzce, have now entered production. The project titled *Beekeeping, Honey Forests and Sustainable Development*, implemented by DAGEM, won the 2011 European Enterprise Award, significantly enhancing international awareness of the Yığılca bee (Kekeçoğlu, 2021). As a result, national and international demand for Yığılca queen bees has been steadily increasing.

To support the development of beekeeping in Düzce, a comprehensive study was conducted to examine the structure of the sector and its challenges. Key issues identified include insufficient technical knowledge, inadequate colony management and feeding practices, failure to use ecotypes suited to local conditions, errors in overwintering preparation, and incorrect practices in combating bee diseases and pests. Based on these findings, a strategic roadmap was developed for the future of beekeeping in Düzce (Kekeçoğlu et al., 2013; 2014).

Kekeçoğlu et al. (2013), conducted face-to-face interviews with 412 beekeepers from 245 villages in Düzce and its districts to identify colony losses and challenges related to bee health. According to the findings, 81.2% of beekeepers experienced winter losses, while 18.8% did not. The causes of colony loss included queen loss (39.8%), Varroa infestation (23.8%), starvation (21.9%), and robbing behavior (3.9%). Additionally, 89.8% of beekeeping operations reported *Varroa* infestation, 51.6% reported wax moths, 18.2% reported *Nosema*, and 13.11% had American foulbrood disease (Kekeçoğlu et al., 2013).

The study concluded that there were significant shortcomings in overwintering preparation, colony management, and disease diagnosis and treatment. In response, several projects were launched to address these issues. The average age of beekeepers in Düzce was found to be 50; 73.1% were primary school graduates, 14.1% had completed high school, and 20.9% relied on beekeeping as their primary source of income. Although these figures have not changed dramatically, the average age has decreased slightly, and more young people and women are now entering the profession.

In 2013, 620 individuals were members of beekeeping associations—59.2% of them belonged to the Beekeepers' Union and 24.5% to the Honey Producers' Union. Today, that number has risen to 1,020 registered members. Regarding bee races, a 2013 study found that 61.5% of beekeepers preferred local ecotypes and 34.7% used Caucasian queens. However, problems related to access to high-quality breeding queens persist.

Approximately 46.8% of Düzce's beekeepers practice migratory beekeeping. The preferred nectar sources for honey production are sunflower (62.96%), chestnut (54.32%), wildflowers (22.22%), canola (11.73%), and Rhododendron (11.73%). According to the study, 79.1% of respondents considered beekeeping a secondary income source, 10.7% practiced it as a hobby, and only 11.4% relied on it as their primary livelihood (Kekeçoğlu et al., 2013; 2014).

In terms of honey production, Düzce ranks 54th in Türkiye with 551 tons and 46th in beeswax production with 22.117 tons. The province hosts 713 beekeeping enterprises and 59,911 Langstroth-type hives, making it one of the few provinces that no longer use traditional hives. Apart from honey and beeswax production, there are three queen bee production facilities in the districts of Yığılca, Çilimli, and Kaynaşlı, each with a capacity of 3,000 queens, totaling 9,000 queens annually (Anonim, 2020).

Since 2012, the number of beekeeping enterprises and hives in Düzce has steadily increased each year. Honey yield per hive has also shown improvement in the last three years compared to earlier periods. The highest honey production to date in Düzce was recorded in 2019 at 552 tons. For beeswax, the highest figure was 47 tons in 2015, and the lowest was 15 tons in 2017. As beekeeping is a nature-dependent activity, production volumes fluctuate annually. In years with heavy rainfall during nectar flow, honey yields tend to decline (Albayrak and Bayır, 2019). (Table 2).

Table 2. Annual honey and beeswax production, number of enterprises and hives in Düzce province (Anonym, 2020; TÜİK, 2023; TEPGE 2021, 2022, 2023, 2024)

Years	Honey(Tons)	Beeswax (Tons)	Number of Enterprises	Number of Hives	Honey Yield (kg/hive)
2012	470	-	442	36.164	12.99
2013	518	26	491	43.611	11.88
2014	470	19	530	48.222	9.75
2015	421	47	578	52.051	8.08
2016	450	23	610	53.266	8.45
2017	481	15	637	54.971	8.75
2018	540	22	674	60.356	8.95
2019	552	22,1	711	59.911	9.21
2020	518	21	713	58.473	8.85
2021	693	21	713	63.943	10.8
2022	531	16	744	65.903	8.1
2023	412	14	793	52.314	7.9

An examination of production data related to apicultural products in Düzce reveals that, in addition to honey and beeswax, other bee products such as pollen, propolis, and royal jelly are also produced (Kekeçoğlu et al., 2014). However, the limited production of these high-value-added products is primarily due to beekeepers concerns about market access (Kekeçoğlu et al., 2014). It has been noted that as the demand for bee products such as royal jelly, bee venom, honey, and pollen in the pharmaceutical and cosmetic sectors increases, their production is also expected to rise (Kekeçoğlu et al., 2014). Therefore, beekeeping in Düzce holds strong potential to be transformed into a high-value economic sector. Based on the numerical data presented in Table 2 and field research findings, the following annual revenues are estimated for Düzce: 100 million TL from honey, 3 million TL from beeswax, 700,000 TL from raw propolis, 1.5 million TL from processed propolis, 600,000 TL from pollen, approximately 700,000 TL from royal jelly, and approximately 2 million TL from queen bee production. The total economic contribution of beekeeping to Düzce's local economy exceeds 120 million Turkish Liras. This figure could be significantly increased through the production and value-added processing of next generation bee products such as bee venom, bee bread (perga), and apilarnil.Beekeeping is closely associated with forest ecosystems. Approximately 50% of Düzce's land area consists of forested terrain. This provides a valuable opportunity for beekeeping activities, which are best conducted away from areas subjected to chemical spraying and do not require flat or fertile agricultural land. The large extent of forest cover, along with the presence of high-nectar-yield plant species such as chestnut, linden, and *Rhododendron*, and the unique Yığılca honey bee ecotype, give Düzce significant potential to become a leading region in the beekeeping industry. Furthermore, due to the abundance of wood resources in these forest areas, the production of beehives could also be developed as a complementary local industry in Düzce.

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The Negative Impacts of Migration on Agricultural Production

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Abstract

Agriculture is a main source of economic and food security in low- and middle-income countries and there is a growing trend of migration from rural to urban areas and towards developed countries. Migration causes a loss of agricultural productivity due to many factors in which the main is shortage of agricultural workers in rural areas. Other factors including improper usage of fertilizers for better growth and production of crops, Households with more migrants have difficulties in dealing with harsh weather to get more agricultural yield. Those regions which have higher rate of male migration have problem to hire manpower for agricultural work. Then women are playing these roles properly, but they receive discrimination because many people believe that these works are specified for men. This discriminate behaviour leads to the potential for less agriculture production. Migration also causes diseases to spread in crops, humans and animals. Crop and animal diseases led to reduction in agricultural production and human disease cause reduction in farm workers. This labor shortage causes difficulty in crop management like planting, weeding and harvesting. It also causes a rise in salaries of agricultural workers which increases the cost of growing crops and less profit from agricultural production.

Key Words: *Agriculture production, Migration, Manpower, Crop management, Fertilizer*

Introductıon

Agriculture plays a significant role in promoting economic growth, reducing poverty, and enhancing food security in many developing nations. Agricultural productivity is decreasing because of rural-urban migration, even while emerging nations are working to end poverty, hunger, and malnutrition. Due to the rapid pace of urbanization in emerging nations and the fact that people are moving from rural to urban regions more quickly than in the past, there is a risk of future shortage of food and other agricultural products if nothing is done (UK AID, 2016).

Agriculture output can be significantly impacted by migration, both at the movement's origin and destination. The number of individuals traveling worldwide is rising annually. Most migrants are moving inside their own countries, from rural to urban areas, despite the common misconception that they mostly leave their place of origin, according to recent statistics. About 281 million individuals moved in 2020 according to the report of United Nations department of economics and social affairs (UNDESA, 2020).

This extends to about 4 percent of the world's population that will be living abroad in 2020. High remittances that migrants send to their family back home, scholars contend that migration is now an essential component of rural livelihoods in many low- and middle-income countries (LMICs) (Mathew, 2014; Obi et al., 2020; Tuladhar et al., 2014). In several LMICs, remittances have played a key role in rural development (Mohapatra and Ratha, 2010). According to a recent World Bank analysis, around US$ 626 billion entered LMICs in 2022, and this amount is anticipated to rise in the years to come (World Bank, 2022). Remittances are becoming a significant source of off-farm income and a significant addition to the national gross domestic product in many developing nations where agriculture is a significant industry (ADB, 2017; Koczan et al., 2021).

Migration affects the nations of origin and destination in both good and bad ways. As a result, migration has emerged as a significant issue in public discussions of the global economic, social, and political spheres (Castles and Miller, 2014). A significant factor contributing to the labor shortage in LMICs is migration. Numerous studies have evaluated the benefits of labor migration for the rural welfare of the countries of origin, including reducing poverty (Adams and Page, 2005; Lokshin et al., 2010; Wagle and Devkota, 2018; Zhu and Luo, 2010; Nguyen et al., 2015), food security (Isoto and Kraybill, 2017; Mora-Rivera and van Gameren, 2021; Nguyen et al., 2017), improving health (Berloffa and Giunti, 2019; Gustafsson, 2018), reducing inequality (Agwu et al., 2018), consuming calories (Karasoy, 2017), managing natural resources (Bierkamp et al., 2021; López-feldman and Chávez, 2016), improving nutritional intake (Isoto and Kraybill, 2017), and improving education (Amuedo-Dorantes and Pozo, 2010; Edwards and Ureta, 2003). However, the detrimental impacts of household labor migration in LMICs have only been the subject of a small number of research.

Negative consequences, such as the loss of productive labor, can also occur in a family with labor migrants (Paudel et al., 2019a). These consequences can eventually impact labor dynamics at the household and community levels as well as the availability of labor in agriculture. Crop production and farm earnings are decreased when workers

leave the home and community, raising rural salaries and crop cultivation costs (Duda et al., 2018; Yamauchi, 2016; Zhang et al., 2014). However, many households in developing nations depend on agriculture as their primary source of income and subsistence, even when there are migrants living there. A household may concurrently experience both good and negative consequences under such circumstances.

The loss of productive labor and a drop in agricultural production and profitability might have a negative impact, while an increase in off-farm income through remittances could have a positive one. However, migration's overall effects are complicated. In terms of rural development, nutrition, food security, agricultural capacity, and the larger rural economy, it can have long-lasting impacts on both the origin and destination areas (Zezza et al., 2011; FAO, 2017; State of Food and Agriculture, 2018).

The broader effects of migration on both origin and destination are examined here.

Gender-based prejudice in the agriculture area

In regions where there is gender-based migration imbalance, with frequently more males departing than women, the agriculture industry may be indirectly impacted, eventually affecting productivity. Research indicates that regions with a greater male migration rate also have difficulties hiring males for agricultural management roles. More women are effectively establishing themselves in farm management jobs since fewer males are available to fill these posts, which are typically held by men in these areas. However, women are experiencing prejudice and unjust treatment since many in the sector believe that a male should fill this function. In addition to having a negative effect on the health of the women who hold these jobs, prejudice can also make it more difficult for the company to succeed. One of the numerous detrimental effects of institutional gender discrimination is the potential for a decline in agricultural production. There is no shortcut to this problem. Addressing gender disparities at their source requires a variety of integrated approaches over an extended period (Zezza et al., 2011; FAO, 2017; State of Food and Agriculture, 2018).

Disease Spread

Research has shown that cross-border migration may contribute to the spread of disease, which might have a detrimental effect on agricultural output and industry overall. Migration can affect the spread of illnesses in humans, animals, and crops which may have a negative effect on agricultural output. Agricultural diseases have the potential to directly reduce agricultural output, and their effects can linger for years. Human and animal diseases can also affect agricultural output; for instance, if a workforce is affected, a farm might not have enough workers to harvest its crops. Alternatively, the framework may suffer if a crucial animal species is affected, which may also have a similar result (Zezza et al., 2011; FAO, 2017).

Impact of migration on fertilizer use efficiency

Increasing fertilizer application is a crucial step in raising agricultural output, however overuse of fertilizers has led to major environmental issues (Wu et al., 2018). Due to a shortage of workers for on-farm work, migration may lead farmers to apply all their fertilizer at once rather than gradually, depending on the demands of plant development (Ma et al., 2017). Migration mostly reduces labor, which impacts the efficiency of technological and fertilizer usage. This is because households with a higher number of migrants have a harder time adapting to weather, plant development, and natural calamities (Sauer et al., 2015). Migration can therefore, on the one hand, reduce the amount of manpower available for agricultural output, which in turn can reduce farm technical efficiency. However, because migrant households have limited agricultural labor, they choose one-time fertilization, which will result in losses of fertilizer and worse fertilizer usage efficiency than spreading fertilizer over time.

Impact of migration on agricultural productivity

Several household and farm-level factors can influence the choice to migrate (Maharjan et al., 2013). Since agriculture is the primary source of income for many households in developing nations (FAO, 2014), a few other factors, such as farm size, household size, land typologies, land productivity, farm management techniques, and climate, influence their decision to move. This makes it possible for us to connect household labor migration to factors including agricultural productivity, labor shortages, crop cultivation costs, farm profitability, and off-farm income.

Communities are experiencing a labor shortage, and rural salaries are rising because of households losing productive workers (Wang et al., 2016; Wiggins and Keats, 2014; Zhang et al., 2014). Even though smallholders often have a lower land-to-labor ratio, their inclination to recruit laborers is impacted by labor shortages and rises in rural wages (Paudel et al., 2019b). There are two ways in which this affects agricultural productivity and output. First, high salaries raise labor prices and crop-growing expenses for farmers, which lowers farm profitability, particularly if remittances aren't utilized to buy better agricultural technology. But for certain households that depend entirely on agricultural labor for their income, raising rural wages may improve their welfare.

Second, farmers might not be able to engage enough workers because of shortages, which would make it more difficult to complete necessary crop management tasks including timely weeding, planting, harvesting, and threshing (Paudel et al., 2019a). Due to labor shortages, timely crop management is inefficient, which lowers agricultural production and profitability and has a detrimental effect on the agricultural economy. Thus, it is empirical to investigate possible trade-offs and synergies between family labor migration and agricultural productivity, production costs, farm profitability, and off-farm income.

According to 30% of all respondents, the primary reason for the drop in agricultural output is migration from rural to urban areas. They said loss of agricultural labor is the primary effect of rural-urban migration, according to people in the examined regions, including the leaders. Since many fields in rural regions are excavated by adults, most people think that if nothing is done to address this issue, agricultural productivity will decline, and poverty will develop. Rural migration also contributes to the rise in agricultural output prices. People claim that because of the high level of market demand, prices rise when agricultural production declines. They claim that if rural-urban migration keeps up, agricultural output will rise significantly (Niyonzima, 2023).

Potential direction

The agricultural sector should get ready to gain from migration by utilizing its potential to boost production and improve the region's overall economic well-being. Additionally, the sector should be conscious of the possible harm that migration may do to farming and put plans in place to anticipate and address these issues.

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Innovative Trends in Food Production of Europe

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Abstract

Food has been evolved in recent years as consumer demand for as they think food is not just to satisfy hunger but its directly impact their health. Scientists are trying to formulate novel food products by blending foods or by adding some additives to natural foods or byy using some technological methods. Some scientific methods like biotechnology and animal and plant breeding also can produce novel food products. There are some innovative methods which can be used to increase the shelflife of food products including edible packaging, coating and microencapsulation. Processing of agricultural raw material for food production makes the food industry one of the most important industry in European Union. Thus food industry has to adopt innovations in raw material and production methods to compete with other industries and fulfill the consumer demand. Food Innovations include scientific and technological procedures for food processing to make it more appealing for customers. Functional foods include probiotics and vegan products are examples of food innovations and now are trending in european union.

Key Words: *Food industry, Innovation, Functional food, Packaging, Vegan products*

Introduction

The food industry is one of the most important sectors in the European Union due to its high economic importance. In most countries, food consumption has peaked, and the European food market appears to be extremely saturated (Gracia and Albisu, 2001). In the European food system, this type of competitive climate leads to a constant search for new goods, procedures, and services (Gracia and Albisu, 2001), which enables industries to differentiate themselves from rivals and satisfy customer demands (Menrad, 2004). Institutional research and development operations, which are often thought to produce innovations, universities and research institutions are widely recognized to play a dominant role (Fearne et al., 2013; Acosta et al., 2011, 2015; Garcia-Alvarez-Coque et al., 2015). Transferring scientific and technical information to industries has therefore been the primary goal of innovation programs (Coenen and Moodysson, 2009; Arias-Aranda and Romerosa-Martinez, 2010; Acosta et al., 2011; Muscio and Nardone, 2012; Moodysson and Zukauskaite, 2014).

The processing of agricultural raw materials and the provision of food make the food industry one of the most significant sectors of the national economies of Italy and the European Union as a whole. As a result, several writers emphasized its importance in relation to employment and economic production (Menrad, 2004). The food business has historically been viewed as a field with low research intensity on innovation in literature (Christensen et al., 1996; Garcia Martinez and Briz, 2000). Nevertheless, innovations defined as new goods, procedures, or services are acknowledged as a crucial tool for businesses in the food sector to differentiate themselves from rivals and meet customer demands (Menrad, 2004).

Consumer demand in the food production sector has evolved significantly over the past ten years; in fact, consumers now more strongly think that food directly affects their health (Mollet and Rowland, 2002; Young, 2000). So now meals are designed to avoid nutrition-related disorders and to promote physical and mental well-being, rather than only to satisfy hunger and supply the required nutrients (Menrad, 2003; Robertfroid, 2000b).

Innovation in the food industry

Introduction of innovative foods and new scientific & technological methods in food processing are the two key examples of food business innovations in recent years. Innovations in the food sector are frequently focused on creating significant substitutes, adhering to dietary guidelines, or meeting laws governing food additives. They can concentrate on aspects of food technology, such as process engineering, product formulation, food attributes, or customer demands, and are often new consumer goods and services. Furthermore, to create food that meets the dietary, individual, and social demands of every community, they must integrate technical innovation with social and cultural innovation. Researchers consider functional food to be one of the most intriguing areas of study and invention among all the advancements offered in this business (Annunziata and Vecchio, 2011; Jones and Jew,

2007; Siro et al., 2008). The rising expense of healthcare, the constant rise in life expectancy, and older people's desire for a higher quality of life in their later years all contribute to their importance (Kotilainen et al., 2006; Robertfroid, 2000a, 2000b).

Functional foods

Fortified food products with unique constituents have beneficial physiological effects, a study on the connections between nutrition, sensory satisfaction, fortification, and physiological system modulation led to the first use of the term "functional food" in Japan in 1984 (Hardy, 2000; Kwak and Jukes, 2001). Functional meals have cholesterol-lowering products which reduce the risk of certain diseases, enhance the body's overall condition, and may even be used to treat certain illnesses (Mark-Herbert, 2004; Menrad, 2003; Side, 2006). Probiotics have recently taken the lead in the functional food industry in both Europe and Japan, with over 370 products introduced globally in 2005 (Ouwehand, 2007). The most researched and often utilized probiotics are bifidobacteria and lactic acid bacteria (LAB) (Kociubinski and Salminen, 2006). Probiotics are mostly sold in Scandinavia, the Netherlands, Switzerland, Croatia, and Estonia, with growing markets like Greece, France, and Spain, as recently noted by Makinen-Aakula (2006).

Technological process

Food processing has always made use of technology. Its use in the development of new functional foods has a long history of successfully controlling deficiencies in vitamins A and D, several B vitamins (thiamine, riboflavin, and niacin), iodine, and iron. Formulation and blending constitute a straightforward, affordable, and adaptable technology (Betoret et al., 2011). The scientific community, consumers, and food manufacturers have paid more attention to this category of food products in recent years due to the growing significance of dietary compounds and the associated health benefits, which presented an excellent opportunity to improve public health (Karaaslan et al., 2011; Kim et al., 2010). Additional options include biotechnology and animal breeding, which offer the potential to produce better food products (Laible, 2009; Matsushita et al., 2007; Zhu et al., 2008), as well as agriculture and livestock, which serve as the main source of the nutrients needed by humans (Zhao and Shewry, 2011).

Technologies are made to stop physiologically active substances from degrading. The two that are most passionately contested in scientific literature are edible films and coatings, which refer to any kind of material used to encase different foods in order to prolong the shelf life of the product that may be consumed with food (Pavlath and Orts, 2009); and microencapsulation, which involves enveloping small solid particles, liquid droplets, or gases in a coating based on the embedding effects of a polymeric matrix (Betoret et al., 2011). Vacuum impregnation is thought to be a practical method of introducing desired solutes into the porous structure of foods, changing their original composition. This has the high potential to carry active ingredients that can lower the risk of pathogen growth on the food surface and provide specific nutrients (Watanabe et al., 2011).

The goal of recent technology was to create customized functional meals. Given that dietary recommendations that are suitable for one person may not be suitable for another, nutrigenomics considers the relationship between food and a person's genome and the ensuing downstream impact on their phenotype (Ferguson et al., 2010). Although this cutting-edge technology is still in its infancy and many elements are still unclear, it has the potential to open a wide range of options in the field of functional foods (Penders et al., 2007; Ronteltap et al., 2007). Furthermore, there are currently only a few instances of clinical trials employing these technologies, so many problems need to be resolved before the genomic approach is accepted as a means of directing food development or nutritional advice (Betoret et al., 2011; Kaput and Dawson, 2007).

Vegan trend in Europe

Food companies embark on plant-based food-related sustainable innovation journeys that how these foods might eventually result in a socio-technical regime of sustainable food production and consumption (Geels et al., 2008). As evidenced by the gradually rising number of vegans and plant-based diet adherents, veganism is a modern and developing social movement that has recently expanded in Western industrialized countries (Strecker, 2015). A plant-based diet is being aggressively promoted by national health research agencies in several European nations to improve public health and slow down climate change (Appleby et al., 2011; Dyett et al., 2013). The output of animal feed has increase rapidly in recent decades, as seen by Italy, where the Mediterranean plant-based diet has long been the most popular diet. According to 2017 research by the Italian Society of Human Nutrition, government institutions and health groups ought to encourage Italians to adopt a vegetarian diet (Agnoli et al., 2017). In the meantime, Environmental policies are considered necessary to help Norwegian consumers make climate-friendly food choices because, in Norway, researchers have found that informing consumers about the health or climate benefits of eating less meat has had little effect (Austgulen et al., 2018).

According to a Danish survey consumers are clearly divided into those who have a good attitude and those who have a negative attitude toward plant-based diets. To boost the consumption of plant-based meals, researchers suggested that future consumer campaigns address concerns expressed by regular meat eaters such as the

preparation, taste, and skepticism regarding the low protein content of plant-based diets (Reipurth et al., 2019). In addition to having an influence on sustainable consumption practices (Büchs et al., 2015), the food business is also taking notice of the rising popularity of veganism and plant-based diets (Pojic et al., 2018).

Food industries have needed to be ready to swiftly provide new items in response to shifting consumer expectations (Traill and Meulenberg, 2002). As a result, businesses in the food industry have had to develop marketing skills in addition to scientific and R&D capabilities, and produce novel goods based on market research. Several policies within the European Union, such as the Common Agricultural Policy, impact food production and consumption. Furthermore, the entire food production system depends on farmers, merchants, consumers, and municipal governments (Westhoek et al., 2011). Now, neither the decrease of meat consumption nor the promotion of sustainable eating habits is the goal of such programs (Dagevos and Voordouw, 2013; Hansson et al., 2018; Westhoek et al., 2011). Without strong incentives, manufacturers who launch new vegan products appear to be responding to customer demand and the expanding vegan movement, reducing manufacturing costs, or addressing environmental issues on their own initiative.

Due to their observable efforts in creating and introducing new plant-based items, major corporations have viewed the vegan trend as a growing and sustained phenomenon. By developing cutting-edge goods and production technology, businesses may also be seen as playing a pioneering role in introducing new, inventive vegan products to mainstream customers in their local and national marketplaces. Rogers (2003) indicates two significant factors of the adoption rate of innovations are compatibility and added value. Conversely, the suitability of vegan products depends on how well these innovations fit with consumers' preexisting preferences and expectations (Dedehayir et al., 2017).

Innovation in Traditional Food Products

In a competitive global food market, manufacturers must innovate to preserve and grow their market share (Guerrero et al., 2009). Researchers find a common criterion that improvements in traditional food items must guarantee maintaining the original "taste" and "flavour" to determine whether innovations may be effective (Guerrero et al., 2012; Stolzenbach et al., 2013). In fact, several market research have revealed that customers have unfavorable emotional reactions to processes that alter conventional items (Stolzenbach et al., 2013). According to Guerrero et al. (2009), the modifications must effectively preserve the notion of traditional products, which are predicated on the idea of a basic, natural, simple, and pure product, particularly in the sense that little to no alteration has taken place after the first manufacture. Otherwise, according to other academics, the "new haute cuisine" is seen as a special setting where conventional food preparation and ingredient changes might take place (Guerrero et al., 2009; 2012). Accordingly, innovative techniques used at the restaurants of famous haute cuisine chefs have been examined in the most recent management studies (Messeni Petruzzelli and Savino, 2014, 2015).

Researchers in Nordic and Southern European nations are equally interested in investigating technologies that might impact conventional food items. The connection between a region's history and its traditional cuisine is a key feature that is recommended for growth in Southern nations (Guerrero et al., 2009). Studies of Nordic settings, where chefs, authors, and specialists emphasize the necessity "to continue using local, regional, and national raw goods," also revealed the connection between traditional food items and certain geographic regions (Amilien and Hegnes, 2013). In the context of the Noma restaurant, where studies determined that successful new dishes are mostly based on the exploitation of traditional Nordic ingredients, this method serves as inspiration for the new dishes created there (Messeni Petruzzelli and Savino, 2014).

Remarkably, a recent study on Italian haute cuisine discovered the rise of a new tactic: new products are created by combining traditional ingredients with other ingredients and by utilizing methods from other, far-off cultures (Messeni Petruzzelli and Savino, 2015). The cultural backdrop of Southern European nations, where ethnicity is seen as an acceptable source of invention, may help to explain this final innovation method (Guerrero et al., 2009). Furthermore, studies conducted on Southern European nations have demonstrated that any prospective improvements pertaining to traditional food items must be health-oriented, such as enhanced or functional foods and the decrease of salt, fat, and sugar (Guerrero et al., 2009, 2010, 2012). Conversely, Nordic nations seem to have a more critical stance toward innovation in traditional food items, as they are already regarded as healthy (Guerrero et al., 2009, 2010, 2012).

Remarkably, research in Nordic European countries paid more attention to the "Innovation in traditional food products" than Southern European countries. Furthermore, the results of this stream also appear unexpected. Southern European consumers appear to be more receptive to changes in traditional food goods if those changes improve nutritional value by lowering the amount of salt, saturated fat, or sugar while maintaining the original flavor. Conversely, in Nordic food markets, where traditional food products are already regarded as healthy, introducing novelty seems to be quite challenging.

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Comparative Analysis of Water Quality in Dam Lakes of Edirne Province, Türkiye

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Abstract

Edirne Province is located in the northwestern part of Türkiye's Marmara Region. This area is classified as "Agricultural Land" because of its abundant freshwater resources and fertile soils. In the current research, the water qualities of Sultanköy and Altınyazı dam lakes were assessed and compared. Water samples were taken from the reservoir outlets in the autumn of 2024. A total of 12 physicochemical parameters were measured, including dissolved oxygen (DO), electrical conductivity (EC), pH, total dissolved solids (TDS), turbidity (Tur), salinity (Sal), suspended solids (SS), nitrite-nitrogen (NO_2-N), phosphate-phosphorus (PO_4-P), nitrate-nitrogen (NO_3-N), sulphate (SO_4), and ammonium-nitrogen (NH_4-N) using a multi-parameter meter and a spectrophotometer. The results of the study indicated that the water quality in both dam lakes was comparable, with both reservoirs demonstrating first-class water quality for DO, pH, NO_3-N, and NH_4-N parameters, second-class water quality for EC and NO_2-N parameters, and third-class water quality for PO_4-P.

Keywords: Sultanköy Dam Lake, Altınyazı Dam Lake, Water quality comparisson

Introduction

Freshwater pollution is one of the most critical environmental challenges of the 21st century, posing significant threats to aquatic ecosystems, biodiversity, and human health (Helvacıoğlu et al., 2025; Haq et al., 2023; Din et al., 2023; Muhammad et al., 2024; 2025; Tokatlı et al., 2025). Among freshwater bodies, dam lakes play a crucial role in water supply, irrigation and flood control. However, increasing anthropogenic activities, including agricultural runoff, industrial discharges, and domestic wastewater inputs, have led to the deterioration of water quality in these reservoirs (Çiçek et al., 2014; Köse et al., 2020; Varol et al., 2022; Ustaoğlu et al., 2022; Yüksel et al., 2024)

Sultanköy and Altınyazı Dam Lakes are among the most significant reservoirs in Edirne Province, Türkiye, playing a crucial role in regional water supply for both irrigation and drinking purposes. Constructed by the General Directorate of State Hydraulic Works (DSİ) to support agricultural productivity and meet the water demands of local communities, these reservoirs have become vital resources for sustaining both economic and ecological balance (http://www2.dsi.gov.tr/). However, like many freshwater ecosystems, they are increasingly subjected to anthropogenic pressures, particularly from agricultural runoff and domestic wastewater discharge, which introduce excessive nutrients, pesticides, suspended solids, and organic pollutants into the water bodies (Tokatlı et al., 2017; Tokatlı, 2019; 2020a; 2020b).

In response to these environmental challenges, this study aims to evaluate and compare the water quality of Sultanköy and Altınyazı Dam Lakes by analysing key physicochemical parameters. Through a detailed evaluation of these indicators, the research seeks to provide valuable insights into the current state of these reservoirs and contribute to the development of sustainable water management strategies to ensure the long-term protection and usability of these essential freshwater ecosystems.

Materials and Methods

Research area and sample collection

Sultanköy and Altınyazı Dam Lakes, along with the selected sampling stations on these reservoirs, are presented in Figure 1, providing a visual representation of the study area. To evaluate the current water quality status, water samples were systematically collected from the designated stations during the autumn season of 2024, ensuring that potential pollutant influxes were accurately represented in the analysis.

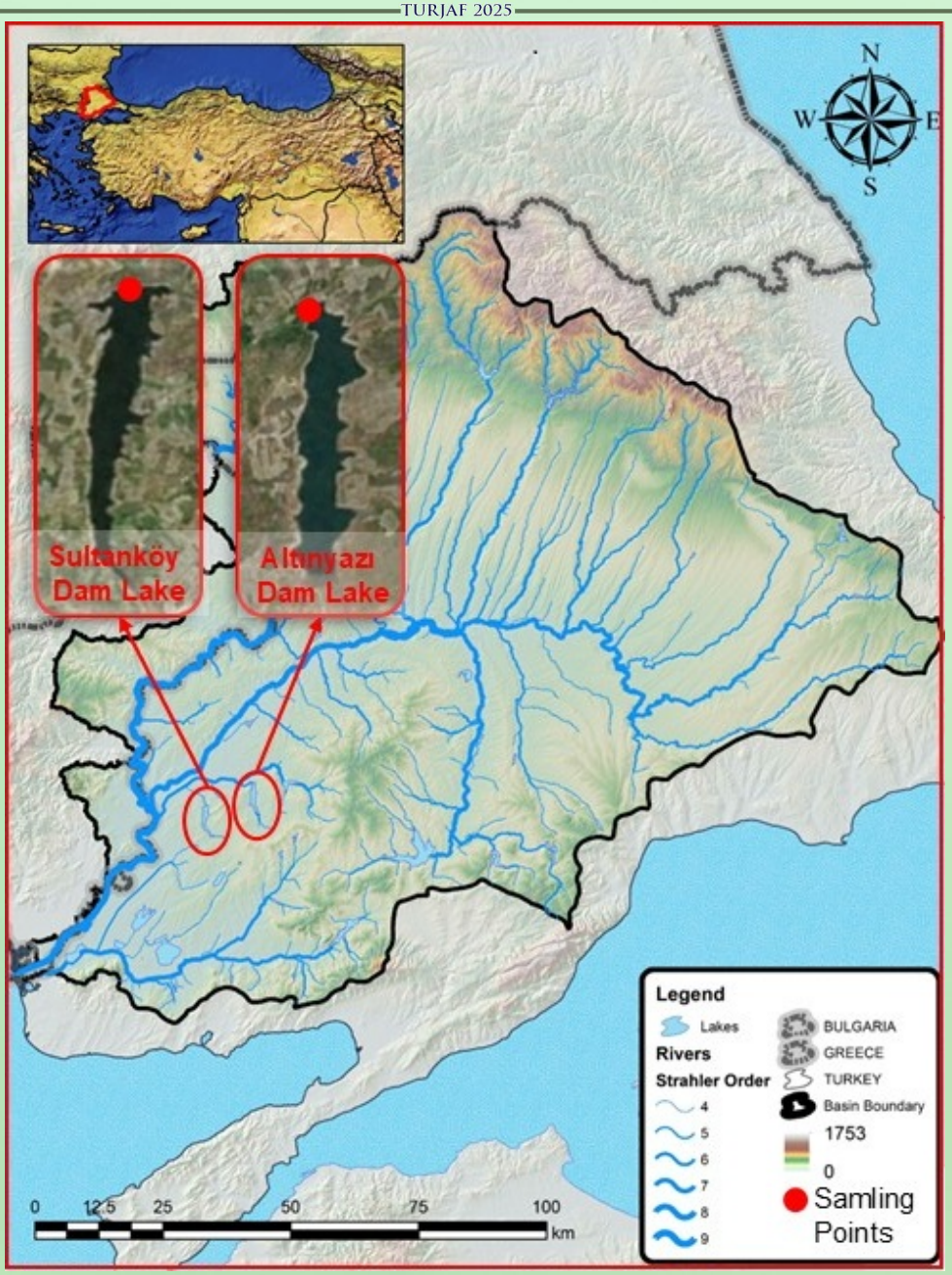


Figure 1. Meriç – Ergene Basin, investigated reservoirs and selected sampling stations

Physicochemical analysis

Dissolved oxygen, electrical conductivity, pH, total dissolved solids, salinity, and turbidity were measured on-site in the field following APHA standards (1998, 2017) using a Hach portable multi-parameter meter and a Hach turbidimeter. The concentrations of suspended solids, phosphate-phosphorus, nitrite-nitrogen, nitrate-nitrogen, ammonium-nitrogen and sulphate were analysed in the laboratory following APHA protocols (1998) using a Hach spectrophotometer and a Hach colorimeter.

Results and Discussion

The detected variables are given in Figure 2. Significant spatial differences in levels of investigated parameters were not recorded and the water qualities of both investigated reservoirs were quite similar. The data of the measured variables in waters of Sultanköy and Altınyazı Dam lakes as follows respectively: 9.62 – 9.40 mg/L for DO; 8.04 – 8.18 for pH; 359 – 313 mg/L for TDS; 734 – 643 µS/cm for EC; 0.36 – 0.31 ‰ for salinity; 47 – 286 NTU for turbidity; 32 – 188 mg/L for SS; 0.021 – 0.023 mg/L for NO_2-N; 0.80 – 0.05 mg/L for NO_3-N; 0.85 – 0.44 mg/L for NH_4-N; 0.30 – 0.21 mg/L for PO_4-P; and 83 – 95 mg/L for SO_4. It was also determined that both reservoirs exhibited first-class water quality in terms of DO (> 8 mg/L), pH (6 – 9), NO_3-N (< 3 mg/L) and NH_4-N (< 0.2 mg/L) parameters, second-class water quality in terms of EC (400 – 1000 µS/cm) and NO_2-N (0.01 – 0.06 mg/L) parameters, and third-class water quality in terms of PO_4-P (> 0.16 mg/L) parameter (TSWQR, 2021). Elevated phosphate levels can lead to eutrophication, a process where excessive nutrients stimulate algal blooms, depleting oxygen levels and disrupting the aquatic food web. In reservoirs, high phosphate concentrations may arise from agricultural runoff containing phosphate fertilizers, wastewater discharge, and soil erosion. Agricultural activities, particularly the use of phosphate-rich fertilizers, contribute significantly to phosphate influx, while wastewater and industrial discharges further augment nutrient loading (Mutlu et al., 2021a; 2021b; Tokatlı et al., 2023; 2024). It is thought that the quite high phosphate values detected in the waters of both investigated dams, which are quite close to residential areas, are caused by agricultural activities and domestic waste.

Conclusions

In conclusion, the water quality data collected from Sultanköy and Altınyazı Dam lakes reveal generally similar characteristics across both reservoirs, with some variations in specific parameters. Both reservoirs exhibit first-class water quality for several critical parameters, including dissolved oxygen (DO), pH, and nitrate-nitrogen (NO_3-N)while they exhibit second-class water quality for electrical condictivity (EC) and nitrite-nitrogen (NO_2-N). However, elevated phosphate levels observed in both lakes suggest a potential risk for eutrophication, which may result from agricultural runoff and domestic waste, given the proximity of these reservoirs to residential areas. Despite their overall good water quality, the higher concentrations of phosphate in both dams indicate that agricultural activities and domestic effluents may contribute significantly to nutrient loading, potentially threatening the long-term ecological balance of these aquatic ecosystems.

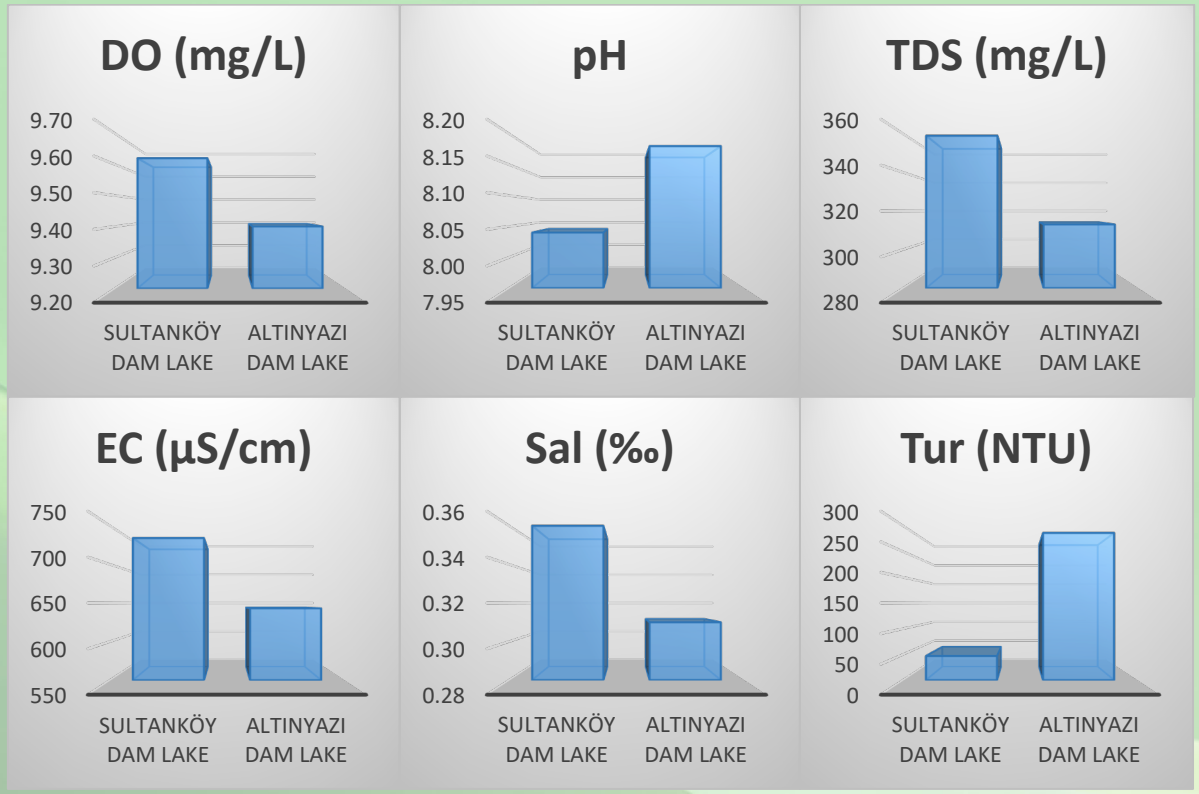


Figure 2. Investigated limnological parameters

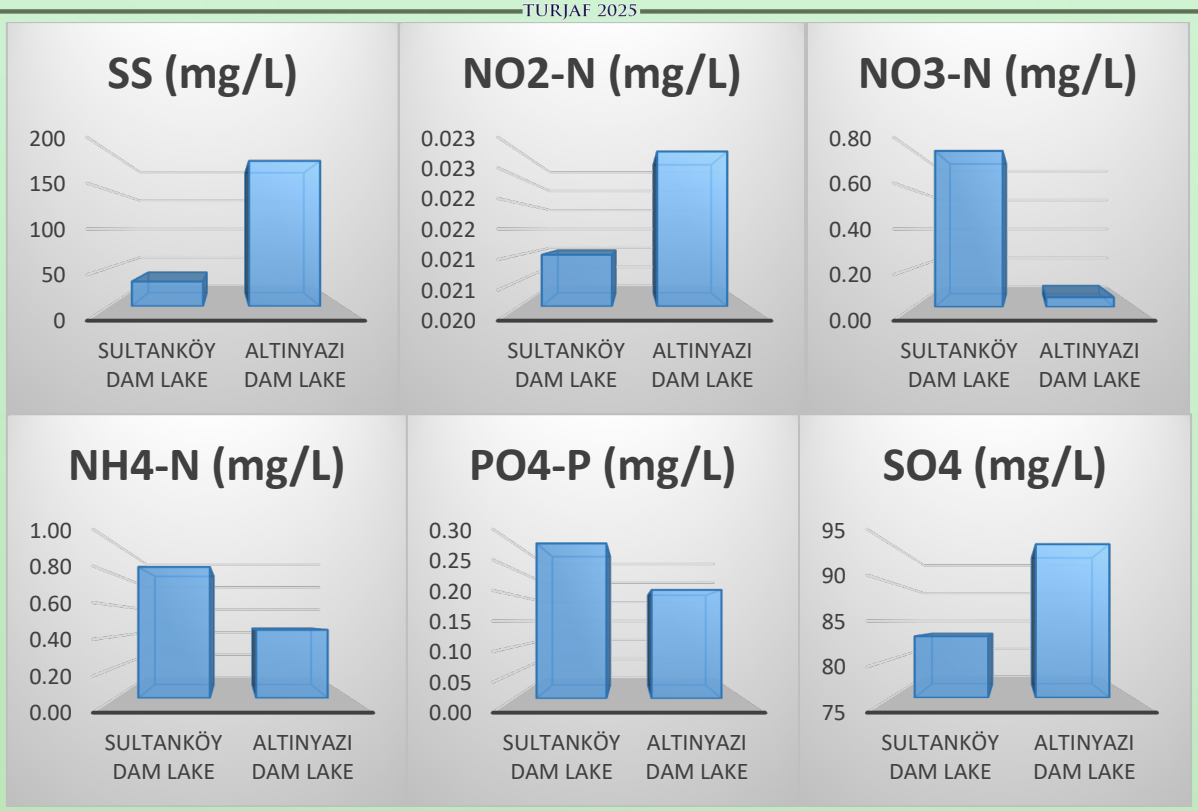


Figure 2. Investigated limnological parameters (continued)

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ID: 482

Quality of smoked-cooked chicken sausage with soy flour and oil

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Abstract
The study aimed to investigate the effect of different levels of soya flour and soya oil on the sensory attributes and nutritional qualities of smoked-cooked chicken sausages. The sausages were manufactured by replacing part of the chicken meat in four treatments with soya flour (T1 =0.0g; T2=94g; T3 =75g and T4 = 52g) and soya oil (T1=0.0ml; T2=56ml; T3=75ml; and T4= 98ml). The products were smoked, cooked and served to forty consumer panelists for sensory evaluation. Consumer panelists evaluated the appearance, texture, juiciness, flavor, taste and overall acceptability of the sausages using a 9-point hedonic scale. Other parameters determined were proximate composition, cooking yield and water holding capacity. The results from proximate composition showed no significant differences ($p>0.01$) in ash and moisture contents of all treatments. There were significant differences ($p<0.01$) in the protein contents, with T2 having the highest protein content and T4 having the lowest. It was observed that fat contents significantly increased ($p<0.01$) as the levels of inclusion of soy oil increased in sausage formulations, and T4 had the highest fat content. There were also significant differences ($p<0.01$) in water holding capacity, with T4 having the highest. No significant differences ($p>0.01$) were observed in the cooking yield and all the sensory attributes evaluated. It was concluded that using higher quantities of flour and lower oil levels resulted in higher protein contents of sausages. While incorporating lower quantities of flour and higher oil levels resulted in higher fat contents. But the levels of soya flour and soya oil used did not affect the sensory attributes of sausage. The best chicken sausage was obtained with 5.35% soya flour and 3.18% soya oil in product formulations.
Keywords: Chicken sausage, sensory attributes, nutritional quality, soya flour, smoked-cooked sausage.

Introduction

The consumption of meat and meat products have long been regarded as an essential part of human diets since they are important sources of a wide range of nutrients that are essential for optimal growth and development. According to You *et al*. (2020) global developments and industrialization have induced a worldwide increase in meat-based diets, including differently processed meat. Such meat-based diets including sausages contain several nutrients in high quantities and quality, however, the contents of protein (amino acids), vitamins, minerals and fatty acids may vary depending on the animal species and processing methods.

A sausage is a meat product obtained from the formulation of different meat ingredients and spices in different proportions to satisfy consumer demands in different regions. According to Carballo (2021) there are varieties of sausages produced worldwide each with outstanding socio-cultural and economic significance, and each local variety is a reflection of the availability and type of raw materials, the climatic influences of the geographical environment, cultural and religious conditions, as well as the knowledge of manufacture passed on from one generation to another. Among the various types of meat, chicken is a popular source of protein due to its low fat, high protein, and balanced amino acid contents. It is therefore recognized by modern consumers as an ideal protein source for healthy eating (Kawecki *et al*., 2021; Hwang *et al*., 2020). According to Barbut (2001) chicken sausages are considered one of the popular foodstuffs among food products and it is consumed across the world. However, during storage, quality attributes of products deteriorate due to lipid oxidation, microbial growth, and also due to chemical reactions (Moawad *et al.,* 2020). Their perishable nature is due to high moisture content, minerals, fat and proteins, which may favour microbial activity leading to a loss in sensory attributes. As a result, the incorporation of some ingredients may maintain the product quality and shelf life (Pagthinathan and Gunasekara, 2021). Thus, food industry experts are continuing to explore innovative means to obtain foods that can meet consumer acceptance for nutritional and sensory characteristics with better storage life based on careful selection and formulation of ingredients available.

According to Zhang *et al*. (2021) soy flour helps to reduce cooking loss, prevent fat separation, and increase yield in meat products. Aside from its use in sausage making, soy protein in particular could have health benefits since it contains essential amino acids that the body needs to function properly. The use of soy flour can also increase the protein contents of other products, which can be beneficial for consumers who require more protein in their diets (Zhang *et al*., 2021).

Thus, many research reports are available on the effects of the addition of soy flour or protein concentrate in sausage making, but there is paucity of work done specifically on effects of using both soy flour and oil on the quality of chicken sausages.

The main objective of this study was to evaluate the quality of chicken sausage through the incorporation of both soy flour and soy oil. The specific objectives included assessments of the impact of soy flour and oil on the physicochemical, nutritional, and sensory attributes of smoked-cooked chicken sausages.

Materials and methods

Study location

This study was conducted at the Meat Science and Processing Unit, Department of Animal Science Kwame Nkrumah University of Science and Technology (KNUST), Kumasi.

Source of experimental materials

10kg of frozen chicken drumsticks were obtained from a local meat shop and spices and seasonings used were obtained from the Kumasi Central Market. Soy oil was purchased from Vester Oil Mills Limited while the soy flour was from ABI'S Special, both located in Kumasi. The chicken drumsticks were thawed overnight at 2°C and deboned, after which the boneless obtained was minced using a table-top mincer with 5mm sieve diameter (MADO Super wolf, Germany).

Sausage production

The total of 6.5kg minced chicken obtained was divided into four portions of 1.754kg, 1.604kg, 1.604 and 1.604kg, each labelled as T1, T2, T3 and T4 respectively (Table 1). The same quantities of spices (20g curing salt, 5g black pepper, 4g garlic powder, 6g nutmeg powder,10g phosphate, 500g ice, 8g chili pepper in each of the minced meat) were added to each treatment. Soy oil and soy flour were added at different levels for T2, T3, and T4 except T1 (control).

Table 1 Ingredients used in product formulations

Ingredients (g)	Treatments			
	Control T1	T2	T3	T4
Meat Sample	1754	1604	1604	1604
Soy flour	0.0	94	75	52
Soy oil (ml)	0.0	56	75	98
Cure Salt	20	20	20	20
Black pepper	5	5	5	5
Garlic powder	4	4	4	4
Phosphate	10	10	10	10
Nutmeg powder	6	6	6	6
Ice and Water	500	500	500	500
Chili pepper	8	8	8	8

The minced meat with all the ingredient was placed in an electric meat mixer and chopped into a consistent paste (meat batter), which was filled into edible cellulose casings and liked to 6cm lengths for hot smoking in a traditional smoke oven. Smoked sausages were cooked in hot water at 80°C to obtain internal temperature of 65°C. The cooked sausages were cooled in ice water, packaged in labelled transparent bags for storage at -18°C for further studies.

Parameters measured

Sensory properties

Sensory evaluation of the sausages was carried out the following day and repeated after 7 days by 35 consumer panellists. The panelists comprised of members and research fellows of the Department of Animal Science. Each sausage treatment sample evaluated was cut into equal sizes of 2cm, after which it was warmed and served to the panel members. Each sample was coded with 3-digit random numbers for the evaluation of sensory attributes for appearance, flavor, texture, juiciness and overall acceptability using 9-point hedonic scale (where 1 is dislike extremely and 9 means like extremely). Drinking water was provided to all panel members to rinse their mouth before and between tasting each sausage sample to avoid carry-on effects.

Proximate analyses and pH of sausages

The crude protein, crude fat, moisture, and ash contents of the products were determined according to AOAC (2023) methods. The pH of sausage samples which were homogenized in deionised distilled water was determined using a digital pH meter (Precisa pH 900-9050, Switzerland).

Thiobarbituric acid reactive substances value (TBRS)

Lipid oxidation in the chicken sausages was measured as TBARS value, according to the procedures described by Alina *et al*. (2012) and Xiong *et al.* (2015). Briefly, 5g of sausage sample without casing was mixed thoroughly with 25 mL of aqueous solution containing 5 mL ≥99.0% trichloroacetic acid, then with 20 mL of deionised water.

The resulting mixture was placed in a 100 mL beaker for 1 h at room temperature, after which it was filtered through a Whatman No.1 filter paper. The filtrate obtained was diluted to 50 mL with deionized water. A mixture of 5 mL of 0.02 M aqueous solution of 2-thiobarbituric acid (TBA) and 5 mL of diluted filtrate was heated in a water bath at 95 °C for 20 min for the formation of a pink colour. The sample absorbance was recorded at 532 nm on a UV/Vis 3200 spectrophotometer and expressed as mg malondialdehyde (MDA) equivalent/ kg sample.

Statistical Analysis

All data generated from the study were analyzed using SPSS version 20.0 using one-way analysis of variance (ANOVA) and significant differences between treatment means were determined using Duncan's test of homogeneity at 1%.

Results and discussion

Sensory characteristics of smoked-cooked chicken sausages

Sensory scores of sausages incorporated with or without soy flour and soy oil are presented in Table 2. The sensory evaluation results showed no significant differences among the samples in terms of appearance ($p = 0.619$), flavor ($p = 0.809$), taste ($p = 0.222$), juiciness ($p = 0.619$), texture ($p = 0.136$), and overall acceptance ($p = 0.897$). These results suggest that all the samples were similar, no matter the type treatment formulation used. Appearance scores ranged from 5.85(T1) to 6.35(T2), flavour was between 6.15(T2) and 6.50(T4), taste ranged from 6.025(T2) to 6.775(T3), juiciness was scored between 5.77(T3) and 6.300(T2), texture ranged from 5.575(T1) to 6.275(T4), and Overall acceptance was scored between 6.425(T1) and 6.700(T2).

Table 2 Sensory characteristics of chicken sausages with or without soy flour and soy oil

Parameters	Type of sausage				Sem	p-value
	T1	T2	T3	T4		
Appearance	5.850	6.350	6.250	6.300	0.147	0.619
Flavor	6.200	6.150	6.250	6.500	0.135	0.135
Taste	6.625	6.025	6.775	6.450	0.133	0.222
Juiciness	6.275	6.300	5.770	6.150	0.156	0.619
Texture	5.575	6.250	6.225	6.275	0.124	0.136
Overall Acceptance	6.425	6.475	6.700	6.550	0.133	0.897

Sensory scale: 1=Dislike extremely; 2=dislike slightly; 3=dislike moderately; 4= dislike; 5=neither like nor dislike; 6=like; 7=like slightly; 8=like moderately; 9=like extremely; Sem=standard error of means

The panel evaluation in this study suggested that all the sensory properties of chicken sausages were not influenced by the addition of soy flour or soy oil at the different levels studied. However, Choi *et al.* (2014) reported that the addition of brewer's spent grain fibre decreased the sensory scores for appearance, flavour, tenderness, juiciness as well as overall liking of chicken sausages. Malav *et al.* (2015) also reported decreased sensory properties for mutton patties produced with cabbage powder. But Fang *et al.* (2019) observed no significant differences in the sensory properties of chicken sausages produced with 3% sugar fibre.

Proximate composition of chicken sausages

The results for the proximate composition of the chicken sausages are presented in Table. 3. All the proximate components considered were significantly different ($p<0.01$) among the various formulations except for the crude ash and moisture contents. The fat content was highest in T4 (23.252%) and lowest in T1 (14.052%), while the protein content was highest in T2 (23.765%) and lowest in T3 (18.289%). Sausages with or without soy flour and oil were similar in moisture contents but significantly higher ($p<0.01$) fat and lower protein contents ($p<0.01$) were observed in soy-treated chicken sausages. These differences are related to the different composition of soy flour and oil ingredients used. Soy flour has higher protein content but lower fat content than soy oil. Chicken sausages with higher oil levels showed differences ($p<0.01$) in fat content compared to the control: the higher the added level, the higher the fat content. Also, the lower the flour added, the lower the protein contents observed. These trends regarding the changing fat and protein levels in meat products depending on the percentages of added ingredients agree with the reports of other authors for several meat products (Trout *et al.,* 1992; Biswat *et al.,* 2007; Peña-Saldarriaga *et al*., 2020).

Moisture contents ranged from 66.395%(T3) to 69.230%(T2) while percentage ash was between 1.480%(T4) and 1.855%(T3), and these were not statistically different ($p<0.01$) among treatments. These observations were similar to results reported by Peña-Saldarriaga et al. (2020) for chicken sausages produced with different chicken by-products as replacement for chicken fat.

Table 3 Proximate composition of the Smoked-cooked sausage

Parameter (%)	Type of sausage				Sem	p-value
	T1	T2	T3	T4		
Moisture	69.079	69.230	66.395	67.690	0.446	0.056
Ash	1.569	1.827	1.855	1.480	0.097	0.527
Fat	14.052[a]	17.745[a]	21.790[b]	23.252[b]	1.386	<0.001
Protein	21.692[b]	23.765[c]	18.289[a]	19.464[a]	0.803	<0.001

[abc]Means in the same row with different superscript are significantly different (p<0.01); soy flour (T1 =0.0g; T2=94g; T3 =75g and T4 = 52g); soy oil (T1=0.0ml; T2=56ml; T3=75ml; and T4= 98ml); Sem=standard error of means

Cooking yield, water holding capacity, and pH

No significant differences (p>0.01) were found among the cooking yield of the four sausage types studied. The mean cooking yields were 82.745% (T1), 86.605% (T2), 78.565% (T3), and 85.145% (T4). These results suggest that the different treatments of soy flour and oil did not potentially have any significant impact the yields of chicken sausages. However, Fang et *al.* (2019) reported significant differences in the cooking yield of chicken sausages. The observed differences in cooking yields reported by Fang *et al.* (2019) could be attributed to the different ingredients used in the different treatments. Where as Fang *et al.* (2019) used different levels of sugarcane fibre and water, the current study utilized soy flour and oil in the manufacture of the sausages.

Table 4 Percentage Cooking Yield, Water Holding Capacity, and pH

Parameters	Type of sausage				Sem	p-value
	T1	T2	T3	T4		
Cooking Yield	82.745	86.605	78.565	85.145	2.016	0.627
Water Holding Capacity	21.200[a]	23.700[b]	34.100[c]	37.100[d]	2.547	<0.001
pH	6.015[c]	5.695[a]	5.890[b]	6.210[d]	0.071	<0.001

[abcd]Means in the same row with different superscript are significantly different. (p<0.01); soy flour (T1 =0.0g; T2=94g; T3 =75g and T4 = 52g); soy oil (T1=0.0ml; T2=56ml; T3=75ml; and T4= 98ml); Sem=standard error of means

There were significant differences (p<0.01) in both pH and water holding capacity among the four chicken sausage types produced. The mean water holding capacities were 34.100% (T1), 37.100% (T2), 23.700 %(T3), and 21.200% (T4). It was observed that higher pH levels in T1(6.105) reduced significantly to 5.89(T3) in the soy-treated sausages. Both pH and water holding capacity have important functions in meat and meat products. Whereas water holding capacity influences juiciness, pH has significant effects of microbial activity and food texture development. The results in this study suggest that the significantly higher water holding capacity in soy-treated sausages could result in more juicier sausages, while their lower pH values may limit microbial activity to cause spoilage in the sausages during storage.

Effects of soy flour and oil usage on lipid oxidation in chicken sausages during storage Thiobarbituric acid-reacting substances (TBARs) value is commonly used to indicate the extent of lipid oxidation in food products. A higher TBAR value suggests a higher level of oxidative spoilage during storage. The observed TBARS values in both control and soy-treated chicken sausages were not significantly different during the entire 3 weeks of refrigerated storage though the levels seem to increase in absolute terms (Table 5). The recorded values during the first, second and third weeks of storage ranged from 0.585(T1) to 0.635(T3), 0.615(T2) to 0.620(T1) and 0.612(T3) to 0.641(T4) respectively.

Table 5 TBARs values in chicken sausages with or without soy flour and oil

Storage Duration	Treatments TBARs				SEM	p-value
	T1	T2	T3	T4		
Week 1	0.585	0.635	0.625	0.630	0.147	0.564
Week 2	0.620	0.615	0.625	0.650	0.135	<0.021
Week 3	0.630	0.613	0.612	0.641	0.137	0.072

Sem=standard error of means; TBARS=thiobarbituric acid reactive substance value in mg malonaldehyde equivalent/kg sample

There were reported reduced TBARS values in sausages (mortadella) with citrus fibre incorporated (Viuda-Martos *et al.,* 2010), goat meat nuggets with incorporation of broccoli powder extracts (Banerjee *et al.,* 2012), and mutton patties with the addition of cabbage powder (Malav *et al.,* 2015). These reductions in TBAR values earlier reported could be due to differences in phenolic contents of soy flour and oil as used in the production of chicken sausages in this study compared to citrus fibre, broccoli powder or cabbage powder used in the production of mortadella, goat meat nuggets and mutton patties respectively. Color of chicken sausages with or without soy oil

The results obtained for colour profile analysis of sausages are shown in Table 6. According to Kamani *et al.* (2017) colour is regarded, first, as a qualitative criterion in meat products and it plays a significant role in consumer's perception and overall product acceptability. There were no significant differences ($p>0.01$) for all the colour coordinates analysed. L* (Lightness) coordinate ranged from 57.453(T1) to 58.001(T4), a* (redness) value was between 17.256(T2) and 18.916(T1) while b* (yellowness) was from ranged from 7.400(T1) to 7.980(T3). Different findings were reported for L*, a* b* values by Peña-Saldarriaga *et al*. (2020) when chicken sausages were formulated with and without chicken fatty-byproducts. Overall, the L* a* b* analysis in this current study suggests that the incorporation of soy flour and soy oil in chicken sausage did not potentially affect the colour of sausages and thus, the consumers were not able to detect any differences in the appearance and acceptability scores during sensory evaluation (Table 2).

Table 6 Color profile of chicken sausages with or without soy flour and oil

Parameters	Treatments				Sem	p-value
	T1	T2	T3	T4		
L*	57.453	57.933	58.000	58.001	0.525	0.012
a*	18.916	17.636	17.256	17.330	0.330	0.031
b*	7.400	7.516	7.980	7.433	0.243	0.021

Means in the same row are not significantly different ($p>0.01$). Sem=standard error of means

Conclusions and recommendation

The use of soy flour and soy oil as ingredients did not affect the sensory characteristics, cooking yield, TBARs and colour of the smoked-cooked chicken sausages. But using higher flour levels resulted in higher protein contents while the incorporating higher oil levels gave higher fat contents in the sausages. The best chicken sausage was obtained with 5.35% soy flour and 3.18% soy oil in the formulation of smoked-cooked chicken sausages. Further study is recommended using soy flour and oil in the formulation of other types of sausage.

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Comparison of Bioactive Properties and Phenolic Compounds of Turkish Coffee, Filter Coffee and Espresso Coffee

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Abstract

In this study, total phenolic content, total flavonoid content, antioxidant activity and phenolic compound contents of Turkish coffee, espresso and filter coffees taken from a local business were compared. Coffee is a popular beverage consumed in social life and has important effects on human health due to its rich bioactive compounds. Phenolic compounds such as caffeic acid and its derivatives, chlorogenic acids and flavonoids make significant contributions to the antioxidant activity of coffee.
When the obtained results were examined, the highest total phenolic and flavonoid amounts were found in espresso coffee as 6185.71 mg GAE/100 g and 4886.90 mg QE/100 g, respectively. The coffee with the highest antioxidant activity was determined as filter coffee (70.25 mmol TE/kg). The dominant phenolic compounds of coffee were determined as caffeic acid (113.73 mg/100 g) and chlorogenic acid (85.47 mg /100 g) in Turkish coffee, and protocatechuic acid (118.27 mg /100 g) in espresso coffee at the maximum level. When the flavonoid contents of coffees were compared, espresso coffee (2709.53 mg/100 g) ranked first in terms of catechin amount , followed by Turkish coffee (1270.80 mg/100 g). It has been observed that coffees prepared with three different methods, namely decoction (Turkish coffee), pressure (espresso) and infusion (filter coffee), contain significant amounts of phenolic compounds and have high antioxidant activity.

Key Words: *Antioxidant activity, Phenolic compound, Espresso, Turkish coffee, Filter coffee*

Introduction

Coffee, the fruit of evergreen sapling-sized trees, is a member of the Rubiaceae family (Kaur et al., 2018). The origin of coffee is Abyssinia/Ethiopia. Coffee, which is said similarly in most parts of the world, took its name from the " Kaffa" region in Abyssinia where coffee is grown (Topalakçı, 2011). Although there are many stories about the emergence of coffee, the most well-known is that it was discovered by goat shepherds. Observing that goats did not sleep at night and were constantly moving after consuming coffee berries, shepherds boiled and drank this fruit, and the coffee adventure that has continued until today began (Kaplan, 2011).
Among the Rubiaceae family, the ones with commercial importance *are Coffea arabica* (Arabica) and *Coffee canephora* (Robusta) (Olechno et al., 2021). *Coffee arabica* (Arabica) and *Coffee canephora* (Robusta), which account for 70% and 30% of global production, respectively (Neves et al., 2019). The chemical composition of coffee beans varies depending on the region where they are grown, the type of soil there, cultivation methods, species, climatic conditions, as well as the processing of the beans, i.e. cleaning and roasting (Zukiewicz-Sobczak et al., 2012). More than 1500 different compounds of coffee beans have been identified, of which 30-40% constitute carbohydrates, 13% fats, and 4% proteins, including free amino acids (Uslu, 2022).
Coffee beans contain aroma compounds, vitamins and minerals. In addition, coffee contains essential oils and phenolic compounds. Among the polyphenols contained in them, chlorogenic (CLA) and caffeic acid are distinguished (Olechno et al., 2020). It is also an important source of compounds with antioxidant potential such as (Çelik & Gökmen, 2018). However, most coffee globally is roasted and the antioxidant profile of coffee changes during roasting due to the degradation of natural antioxidants, the formation of new ones such as melanoidins and the formation of other Maillard reaction products (MRPs) (Nunes & Coimbra, 2007). The taste, quality and phytochemical properties of coffee, the interaction of water and coffee, and the brewing times and techniques are of great importance due to the fact that coffee contains many soluble and insoluble compounds during extraction (Cordoba et al., 2020)There are many techniques used to brew coffee such as (Komes & Belščak-Cvitanović, 2014). In this study, the total phenolic content, total flavonoid content, antioxidant activity and phenolic components of Turkish coffee, espresso and filter coffees purchased from a local business were compared

Materials and Methods

Material

Turkish coffee, espresso and filter coffee purchased from a local business in Konya were analysed after cooling at room temperature.

Methods

Coffee samples were diluted 10-fold to prepare the extracts and made ready for analyses.

Total Phenolic Content

Total phenolic contents of coffee extracts were detected using Folin Ciocalteu (FC) reagent (Yoo et al., 2004). Extracts (0.5 ml) were mixed with 2.5 ml FC reagent and 1.5 ml sodium carbonate solution. For absorbance values, samples stored in the dark at room temperature for 2 h, were measured in a spectrophotometer at a wavelength of 725 nm. The results were recorded as mg gallic acid equivalent (GAE)/100 g.

Total Flavonoid Content

Total flavonoid contents of coffee extracts were determined according to the method described by Hogan et al. (2009) The extracts (1 ml) were mixed with 0.3 ml $NaNO_2$, 0.3 ml $AlCl_3$ and 2 ml NaOH. The absorbance of the mixture was recorded at 510 nm with a spectrophotometer. The results were expressed as mg quercetin equivalents (QE)/100 g.

Antioxidant Activity Determination

Antioxidant activity of coffee extracts was determined using 2,2-diphenyl-1-picrazyl (DPPH) as suggested Lee et al. (1998). After the extracts (0.1 ml) were mixed with 2 ml of DPPH solution, the absorbance values of the samples, kept in the dark for 30 min at room temperature, recorded at 517 nm in a spectrophotometer. The results are given as mmol trolox equivalent (TE)/kg.

Determination of Phenolic Compounds

The phenolic compounds of coffee extracts were detected by HPLC (Shimadzu) equipped with a PDA detector and an Inertsil ODS-3 (5 µm; 4.6×250 mm) column. A mixture of 0.05% acetic acid in water (A) and acetonitrile (B) with a flow rate of 1 ml/min at 30 °C was used as the mobile phase. The injection volume was 20 µL. Peaks were taken at 280 °C using a PDA detector. The elution program was used: 0–0.10 min 8% B; 0.10–2 min 10% B; 2–27 min 30% B; 27–37 min 56% B; 37–37.10 min 8% B; 37.10–45 min 8% B. Total run time per sample was 60 minutes.

Results and Discussion

Total phenolic contents, total flavonoid contents and antioxidant activities of coffees prepared with three different methods, namely decoction (Turkish coffee), pressure (espresso) and infusion (filter coffee), are shown in Table 1. When the results obtained were examined, the highest total phenolic content was found in espresso coffee as 6185.71 mg GAE/100 g, while this value was recorded as 3787.76 mg GAE/100 g and 2212.93 mg GAE/100 g in Turkish coffee and filter coffee, respectively. In a study, the highest total phenolic content in coffees prepared in a coffee (Olechno et al., 2020). In another study, the highest total phenolic content was found in espresso coffee as 9.87 mg GAE mL^{-1}, while the same value was found as 5.05 mg GAE mL(Derossi et al., 2018). In a study conducted Kaur et al. (2018), it was reported that coffee made with the decoction method had higher total phenolic content than coffee made with the infusion method. Considering the literature data, the highest total phenolic content was found in espresso, followed by Turkish coffee and filter coffee.

The highest total flavonoid content was found in espresso as 4886.90 mg/100 g, these values were 1632.14 mg/100g and 875.48 mg/100 g in Turkish coffee and filter coffee, respectively. Uslu (2022)8671.77 mg/100 g) was found to be higher than that of coffee made with the infusion method (8518.71 mg/100 g). According to another study, the total flavonoid content in espresso was detected as 554.78 µg QE/ mL (Jung et al., 2021). In another study, it was determined that coffee prepared with the decoction method (69.24 mg/g) had higher total flavonoid content than the hard infusion method (35.76 mg/g) (Kaur et al., 2018). Among the pressure (espresso), decoction (Turkish coffee) and infusion (filter coffee) methods, espresso had the highest total flavonoid content, followed by Turkish coffee and filter coffee.

The antioxidant activities using the DPPH method were equal to 70.25 mmol TE/kg in filter coffee, 66.64 mmol TE/kg in Turkish coffee and 51.63 mmol TE/kg in espresso coffee. In a study, the antioxidant activity of espresso with the DPPH method (1587.7 mmol TE/L) was found to be higher than that of filter coffee (628.9 mmol TE/L) (Chavez et al., 2022). In another study, the antioxidant activity value was higher in the infusion method (8.51 mmol TE/kg) than in the decoction method (7.38 mmol TE/kg) (Uslu, 2022).

The phenolic compounds of coffees are given in Table 2. Caffeic acid (113.73 mg/100 g) and chlorogenic acid (85.47 mg/100 g) in Turkish coffee, protocatechuic acid (118.27 mg/100 g) in espresso coffee and caffeic acid (55.73 mg/100 g) in filter coffee were determined as the main phenolic acids.

The flavonoid contents of coffees are shown in Table 3. Espresso coffee (2709.53 mg/100 g) ranked first in terms of catechin content, followed by Turkish coffee (1270.80 mg/100 g) and filter coffee (597.33 mg/100 g). In a study recorded by Górecki and Hallmann (2020), caffeic acid (28.37 mg/g) was found in 3-minute brewing, while caffeic acid (27.74 mg/g) was found in 6-minute brewing. In another study, epigallocatechin (0.64 mg/g) was found in a coffee brewed at a medium level (Król et al., 2020).

Table 1. Total phenolic, total flavonoid contents and antioxidant activities of coffee samples

Coffee Samples	Total Phenol Content (mg GAE/100 g)	Total Flavonoid Content (mg QE/100 g)	Antioxidant Activity (mmol TE/kg)
Espresso coffee	6185.71 ± 194.68	4886.90 ± 50.68	51.63 ± 1.43
Filter coffee	2212.93 ± 32.80	875.48 ± 8.25	70.25 ± 0.00
Turkish coffee	3787.76 ± 110.37	1632.14 ± 14.29	66.64 ± 0.08

Table 2. Phenolic acid contents of coffee samples

Phenolic acids (mg /100g)	Espresso coffee	Filter coffee	Turkish coffee
Gallic acid	40.80 ± 0.69	32.33 ± 1.00	2.60 ± 0.04
Protocatechuic acid	118.27 ± 4.23	46.20 ± 2.75	4.87 ± 0.07
Chlorogenic acid	39.27 ± 1.38	52.60 ± 1.78	85.47 ± 3.01
Caffeic acid	32.73 ± 0.27	55.73 ± 2.84	113.73 ± 5.94
Coumaric acid	17.80 ± 1.20	1.33 ± 0.04	1.53 ± 0.03
Ferulic acid	1.67 ± 0.05	4.53 ± 0.12	5.13 ± 0.23
Cinnamic acid	0.67 ± 0.02	0.67 ± 0.02	7.73 ± 0.32

Table 3. Flavonoid contents of coffee samples

Flavonoids (mg /100 g)	Espresso coffee	Filter coffee	Turkish coffee
Catechin	2709.53 ± 18.25	597.33 ± 3.23	1270.80 ± 3.89
Routine	7.73 ± 0.19	6.47 ± 0.20	55.40 ± 1.61
Hesperid	7.00 ± 0.35	0.80 ± 0.03	1.60 ± 0.06
Quercetin	9.73 ± 0.19	4.47 ± 0.05	2.67 ± 0.06
Kaempferol	36.13 ± 0.29	30.60 ± 0.43	29.67 ± 0.53

In this study, bioactive properties of espresso, filter and Turkish coffees, which were obtained a local coffee shop, were analyzed and compared. The highest total phenolic and flavonoid contents were found in espresso coffee, followed by Turkish coffee and filter coffee. Antioxidant activity results were recorded as the opposite of the others, the highest in filter coffee, followed by Turkish coffee and espresso coffee. The main phenolic acids were found to be caffeic acid, chlorogenic acid and protocatechuic acid. The dominant flavonoid was determined as catechin.

Conclusion

In this study, bioactive properties of espresso, filter and Turkish coffees, which were obtained a local coffee shop, were analyzed and compared. The highest total phenolic and flavonoid contents were found in espresso coffee, followed by Turkish coffee and filter coffee. Antioxidant activity results were recorded as the opposite of the others, the highest in filter coffee, followed by Turkish coffee and espresso coffee. The main phenolic acids were found to be caffeic acid, chlorogenic acid and protocatechuic acid. The dominant flavonoid was determined as catechin.

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Effects of Parboiling on Cooking Qualities of the Super Green Rice Variety Grown in Ethiopia

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Abstract

As a result of the parboiling procedure, where the starch in the grains is gelatinized and solidified when cooled, the husk may be removed from the grain during shelling with minimal harm. Nutrient loss while cooking the grain is also prevented as a result of gelatinization. Water was absorbed by the grain's empty spaces during the gelatinization and retrogradation processes. Hence, the absorbed water and nutrient molecules can't leave after the starch has swelled up and cooled. In this study, the Selam rice variety was subjected to three factors: soaking temperatures of 40, 60, and 80°C; soaking times of 6, 12, and 24 hours; and steaming times of 15, 25, and 35 minutes. The control group, non-parboiled rice, was also subjected to the full factorial design, which had a Completely Randomized Design (CRD) arrangement. The samples exposed to the highest time-temperature combinations showed variations in cooking time, swelling ratio, water uptake ratio, and percentage of chalkiness that were statistically significant ($P<0.05$). The cooking duration varied between 8.13 to 12.37 minutes, whereas the control took 9.28 minutes. The swelling ratio varied from 1.04 to 1.57, while the control was 1.26. The water uptake ratio values weren't statistically different, though. The color value difference varied from 8.95 to 19.57. When the soaking and steaming periods were extended to 24 hours and 35 minutes, respectively, for the 80°C soaking temperature, the amount of chalkiness in the grains drastically dropped from 99.48% of the non-parboiled rice to just 0.33%. The highest soaking temperature (80°C), soaking time (24 hours), and steaming time (35 minutes) were generally the best combinations for achieving the best cooking quality of parboiled rice.

Keywords: *chalkiness, cooking loss, cooking time, gelatinization, parboiling*

INTRODUCTION

Rice (*Oryza sativa*) belongs to cereal grain of the family *Poaceae*. For the vast majority of people on the planet, it is regarded as the main food crop (Vijay and Roy, 2018). According to IRRI, it is clear that rice cultivation has an impact on youth employment, food security, and poverty reduction. Rice is a staple food for people in many countries and is one of the most widely grown cereal crops worldwide (Rohman *et al.,* 2014). It is a grain with a diverse genetic makeup that is cultivated in hundreds of different kinds all over the world. One of the most significant food grains for humans has historically been rice due to its vast spread. Two-thirds of the world's population is fed this rice grain (Dhankhar, 2014). About 27% of the energy in low- and middle-income nations comes from rice. In all regions of the world, including Sub-Saharan Africa (SSA), it is one of the food commodities with the fastest rate of growth (Dawit and Tompson, 2020). The most significant crop in West Africa and the third-most significant crop in all of Africa is rice. It is consumed by more than 750 million people in sub-Saharan Africa (SSA) (EIAR, 2019). As opposed to other food crops, rice is ingested as a whole grain, making grain quality factors far more important. Around 618 million tons of rice were produced worldwide each year, of which 50% were converted into parboiled products (Rahimi-Ajdadi *et al.*, 2018).

Rice cultivation in Ethiopia most likely began when wild rice (*Oryza longistaminata*) was discovered in the wet, marshy areas of the Fogera (Amhara) and Gambella plains. In several regions of Ethiopia, rice output has grown consistently (EIAR, 2019). The entire land area has grown since the early 1970s, going from roughly 10,000 hectares in 2006 to about 50,000 ha in 2018. Before rice was introduced, the farmers in the Fogera Plain subsisted on pastoral farming and a modest amount of crop output (Tilahun *et al*., 2018). Gambella from 1973 to 1982, Pawe from 1985 to 1988, and the Fogera plain in the early 1980s were the first places where rice was introduced. The Fogera plain, however, has remained one of the top rice-producing regions among them, having shown a significant number of agricultural modifications related to rice production and its marketing.

According to Takele, (2017) and Dawit *et al*., (2018), Ethiopia is regarded as a significant rice-growing nation in Africa. More than 39 million hectares of Ethiopian land are ideal for growing rice. A little under 30 million hectares are upland, 3.7 million are irrigated, and the remaining area is used for lowland rice. From being the poorest farmers in the area to becoming the richest, the Fogera Plain's rice farmers have improved their quality of life. In the rice processing and marketing industry, private company owners have arisen and prospered (Dawit *et al*., 2018).

Even though rice is growing rapidly by area coverage and demand, the local rice varieties in Ethiopia have low physical and cooking quality attributes. Rice passes multiple steps of processing to be eaten during which it could

be lost quantitatively and qualitatively due to milling at low moisture content, mal-operation of the polishing machine, and impurities with rice grain (EIAR, 2019). According to the study by Da, (2021), there is a very high loss of rice during de-hulling and polishing, when using poor-performance machines and unskilled operators. Parboiling emerged to improve the cooking and milling qualities of rice, where the process involves soaking, steaming, and drying (Ayenew *et al*., 2020). Thus, to solve this problem, parboiling technology has been introduced to Ethiopia recently to gelatinize the starch and harden the kernel.

Ethiopian rice varieties are not yet treated by the parboiling process. Rice consumers are asking the rice research and training center for technologies that could improve the cooking quality of rice. Rice processors in the South Gondar zone are adapting the parboiling process using the Africa Rice GEM parboiling technology. The processors were using firewood or electricity as a source of energy before the introduction of the Africa Rice GEM soaking and steaming apparatus. However, the GEM parboiling technology is easier and uses rice husk burning in a gasifier as a source of power. This study aimed to improve the rice cooking quality and reduce the percentage of chalkiness. The research was expected to enhance the livelihood of farmers and contribute to the betterment of the marketing system. Thus, the objectives of this study were to:

a) study the effect of soaking and steaming time-temperature interaction on the cooking time of parboiled rice,
b) study the effect of the time-temperature combination of soaking and steaming on the water uptake ratio of parboiled rice,
c) investigate the impact of the rice parboiling process on the swelling ratio of rice, and
d) study the effects of parboiling on the percentage of chalkiness and color of the parboiled rice

MATERIALS AND METHODS

Experimental Materials

Domestic lowland rice (*Selam*) variety of 81 kg was collected from Fogera National Rice Research and Training Center (FNRRTC), Ethiopian Agricultural Research Institute.

Experimental Plan

The experiment of parboiling was conducted with a full factorial design of having a completely randomized arrangement. It consisted of three factors with three levels. These are soaking temperatures of 40, 60, and 80°C; soaking time of 6, 12, and 24 hours and steaming time of 15, 25, and 35 minutes. Each treatment was carried out with three replications. The non-parboiled milled rice was the control that passed through the same processes except the parboiling. A control sample of 20-kg paddy was sun-dried (without parboiling) to 14% moisture content and was milled (Hasbullah *et al.,* 2017; EIAR, 2019).

Sample Preparation

Cleaning

According to Ndindeng *et al*. (2015) and Nambi *et al*. (2017), the cleaning of paddy was done based on the different physical properties such as size, density, weight, and properties of impurities. Both the experimental and control groups of collected rice grains were first cleaned very well using a hand-operated winnower. Impurities that were lighter than the paddy were removed by aspiration whereas those that could not be removed by the winnower were cleaned by handpicking.

Washing

The immature grains of the experimental groups were separated by floating in the water Ndindeng *et al*. (2015). The floated grains were removed and only the submerged ones were taken for the next process. Water-soluble dirt in the paddy was removed by washing it in water to prevent the entry of pollutants into the embryo during soaking and steaming. Then, the cleaned paddy was sun-dried and weighed.

Parboiling Process

Soaking

The soaking temperature was 40°C, the first 9 kg of paddy was soaked for 6 hours, the second 9 kg for 12 hours, and the third for 24 hours and left in ambient conditions till the time was up. The same procedures were followed for 60 and 80°C soaking temperatures. Each division of the sample was added into a soaking tank (which was made up of stainless steel, Inox 304), with plenty of water at the water-to-paddy rice ratio of 2:1 (Ndindeng *et al*. 2015; Hasbullah *et al*. 2017). The soaking temperatures and soaking time values used for this study were the medium values that scholars used (Ayamdoo *et al*., 2013; Bello *et al*., 2015; Ndindeng *et al*., 2015; Hasbullah *et al.,* 2017).

Steaming

Each of the samples was soaked for 6, 12, and 24 hours at a temperature of 40, 60, and 80°C divided into three equal parts having 3 kg each (Ndindeng *et al*., 2015). Each of the 3-kg samples was added to a perforated steaming apparatus made of stainless steel (Inox 304) one by one. The amount of water that was added to the steaming apparatus was a 1:2 ratio with the paddy. The paddy did not contact the water directly. It was steam-heated by the vapor released from the steaming tank. Samples from each soaking time were steamed for 15, 25, and 35 minutes of duration without removing the heat source. The steaming time values selected for this study were the medium values used by most scholars (Ndindeng *et al.*, 2015; Hasbullah *et al.*, 2017; Yerragopu and Palanimuthu, 2019).

Drying

The parboiled paddy was dried in the open sun by spreading it on a plastic sheet. It was continuously stirred to avoid over-drying on one side and to protect against the formation of internal cracks. The paddy dried up to 18% moisture content and was placed in the shade until it was slowly reduced to 14% (Ndindeng *et al.*, 2015; Hasan *et al.*, 2019). The moisture content level was checked every 15 minutes, using a rice grain moisture meter KETT J301, Japan (Ayenew *et al*. 2020).

Husking

The dried paddy was husked with a machine, SATAKE SB 2000, SATAKE Corporation, Hiroshima, Japan that was properly adjusted according to the technical manual, and brown rice was obtained (Nambi *et al*. (2017) and Ayenew *et al*. (2020).

Polishing

The brown rice was transferred into the polishing machine SATAKE SB 2000, Satake Corporation, Hiroshima, Japan to remove the bran from the endosperm. The properly adjusted rubber roll machine produced the polished white rice (Ayenew *et al*., 2020).

Determination of Physical Characteristics of Parboiled Rice

Moisture Content

The moisture content of the paddy was measured randomly using a digital rice moisture meter J301, Japan (Ayenew *et al.,* 2020; Paul *et al*., 2020; Bagchi *et al*., 2016) by taking a few grains from the sample. Measurements were taken after soaking, after steaming, during drying at different time intervals, and before husking or polishing to be sure of the 14%. Additionally, the moisture content of each sample was analyzed by the FOSS NIR Systems-6500 machine when the proximate composition was examined.

Percentage of chalkiness

Chalkiness is a level of low transparency of light through the grain. The number of chalky grains in the milled/polished rice was determined by a grain viewer magnifying lens (QUG/A2-SL, U.K.) with fluorescent light. Rice grain is said to be perfectly translucent when it allows light transmission through it. Otherwise, it's considered opaque or chalky. The percentage of chalkiness was determined by taking 10 g of parboiled milled rice from the samples. It was estimated by the following formula (Equation 1) (Ayenew *et al*., 2020; Jittanit and Angkaew, 2020; Sethy *et al.*, 2018).

$$\text{Chalkiness (\%)} = \left[\frac{\text{Weight of chalky grains}}{\text{Weight of sample grains}}\right] \times 100 \qquad (1)$$

Color

Color is an important criterion for the marketing value of parboiled rice. The whiteness color value of parboiled rice decreases to slightly darker (Taghinezhad *et al*., 2015). The overall color of the parboiled rice could be estimated using the formula given below (Equation 2); using Konica Minolta CM-5, Tokyo, Japan (Jittanit and Angkaew, 2020).

$$\Delta E = \sqrt{(L_2 - L_1)^2 + (a_2 - a_1)^2 + (b_2 - b_1)^2} \qquad (2)$$

Where: L_2 stands for the brightness of parboiled rice, while L_1 represents the brightness of non-parboiled rice, a_2 is the red-green color component of parboiled rice, a_1 refers to the red-green component of non-parboiled rice color, b_2 refers to the yellow-blue color component of treated rice, and b_1 stands for the yellow-blue color component of non-parboiled rice (Nawaz *et al*., 2018). According to Taghinezhad *et al*. (2015), soaking at 65°C and steaming time of 4 min gives the highest values of desirable quality of parboiled rice, such as lightness.

Determination of Cooking Quality

Cooking time

According to Ndindeng *et al*. (2015) and Hasan *et al*. (2019), ten grams of milled rice from each sample were poured into 135 ml of vigorously boiled water in a 400 mL beaker and covered by a glass. After about 10 minutes of boiling, 10 grains were taken out one by one every minute with a perforated ladle. The removed grains were immediately pressed between 2 Petri dishes to know whether it was well cooked or not. The cooking continued until a minimum of the 10 grains had no opaque centers. The time taken for that to happen was recorded and considered the sample's optimum cooking time.

Water uptake ratio

The water uptake ratio is the capacity of the rice kernel to suck water when cooked. According to Thomas *et al*. (2013), Chavan *et al*. (2018), and Yerragopu and Palanimuthu (2019), the water uptake ratio (WUR) was estimated by taking 20 g of head rice and cooking in 200 mL of distilled water at 90°C until there was no white core left in the grain. Then water uptake ratio was calculated mathematically by subtracting the weight of the uncooked kernel from the weight of the cooked kernel and dividing by the uncooked kernel using Equation 3.

$$\text{WUR} = \frac{\text{Weight of cooked} - \text{Weight of uncooked}}{\text{Weight of uncooked}} \qquad (3)$$

Swelling ratio

The swelling ratio (elongation ratio) is the extension of rice kernel length due to cooking and water uptake. It was estimated by randomly selecting 10 cooked rice kernels, measuring their lengths by digital Vernier Calliper, and

dividing their mean value by the average length of 10 randomly selected raw rice grains measured by the same instrument (Thomas *et al*., 2013; Yerragopu and Palanimuthu, 2019) using Equation 4.

$$\text{Swelling ratio} = \frac{\text{Length of cooked kernel}}{\text{Length of raw kernels}} \quad (4)$$

Data Analysis

The collected data were statistically analyzed using Statistix-10 software. They were subjected to analysis of variance (ANOVA) to see the statistically significant differences due to the different parboiling treatments and the control (non-parboiled rice). The parameters considered were the percentage of broken rice, head rice yield, milling recovery, physicochemical properties, cooking quality, and nutritional qualities of rice. The statistically significant differences between sample means were analyzed by following a full factorial design arranged in CRD at a 5% level of significance.

Results And Discussions

Interaction Effects of Soaking Time, Soaking Temperature, and Steaming Time on the Quality Parameters of Parboiled Rice

Effects of pre-treatment temperature and soaking time on cooking quality

Table 1 presents data showing the interaction effects of soaking temperature and time on the cooking quality of parboiled rice. The interaction has a significant ($P<0.05$) effect on the cooking quality parameters except for the water uptake ratio. The cooking time ranged from 9.17 to 11.84 minutes, the longest being of samples soaked at 60°C for 24 hours. On the other hand, the shortest cooking times (9.17 and 9.33 minutes) belonged to two samples soaked at 40 and 60°C for 12 hr each. The interaction of the two factors appeared to have a balanced effect on the cooking time of parboiled rice and the values increased for most samples as compared to the control. This finding was corroborated by the report of Chavan *et al*. (2018) who showed that soaking at 85°C for three hours prolonged the cooking time of parboiled rice as compared to non-parboiled rice.

The swelling ratio data of parboiled rice showed significant ($P<0.05$) differences due to the interaction of the two factors. However, the data didn't show any trend with increasing soaking temperature and time. The swelling ratio values ranged from 1.16 to 1.38, the highest being of samples subjected to 40°C for 6 hours. On the other hand the lowest values, 1.16, 1.17, and 1.22 mm/mm, with no statistical difference among them, were recorded for the combination of a soaking temperature of 60°C and all three soaking times.

Chalkiness values were highest (14.78 and 12.56%) for samples subjected to the lowest soaking temperature (40°C) and shorter soaking times of 6 and 12 hours, respectively. On the contrary, the four lowest chalkiness values (0.90, 1.11, 2.01, and 3.56) were of samples subjected to the longest soaking times regardless of soaking temperature. The data showed that the interaction effect of the two factors on chalkiness values was dominated by soaking time, i.e. short soaking time led to high values while long soaking times resulted in low values at each soaking temperature considered in the study. This indicated that the parboiling process conducted for longer soaking times resulted in a higher starch gelatinization rate and formed a translucent grain while short soaking time resulted in minimal gelatinization of the starch in the kernels thus some white spots remained inside the kernels.

The color values of the parboiled rice ranged from 11.57 for samples treated with a combination of 40°C soaking temperature and 6 hours of soaking time to 18.26 for samples soaked at the highest temperature (80°C) for the longest time (24 hours). The data showed increment due to increased soaking time for each soaking temperature with a similar increasing trend among the group of data of the different soaking temperatures exhibiting a balanced influence of the two factors on the color values in their interaction. The trend in the color data is inversely related to that of chalkiness data because the higher the chalkiness in the grains the lower the color difference between the parboiled and the non-parboiled rice grains. This is related to the level of starch gelatinization in the parboiled grain: higher gelatinization leads to lower chalkiness hence higher color difference from that of the non-parboiled grain.

Table 1: Effect of soaking temperature and soaking time on cooking qualities of rice

SkTp (°C)	SkTm (hrs)	CT (min)	SR (mm/mm)	Chalkiness (%)	Color (ΔE)
40	6	$9.42^{f}\pm0.70$	$1.38^{a}\pm0.17$	$14.78^{a}\pm9.67$	$11.57^{g}\pm3.06$
	12	$9.17^{g}\pm0.41$	$1.27^{c}\pm0.16$	$12.56^{b}\pm9.02$	$12.64^{f}\pm2.17$
	24	$10.38^{e}\pm0.86$	$1.26^{c}\pm0.12$	$1.11^{g}\pm1.05$	$15.12^{d}\pm3.34$
60	6	$10.41^{e}\pm1.28$	$1.22^{cd}\pm0.15$	$10.78^{c}\pm5.24$	$13.72^{e}\pm2.85$
	12	$9.33f^{g}\pm1.04$	$1.16^{d}\pm0.14$	$6.56^{d}\pm5.50$	$15.12^{d}\pm1.59$
	24	$11.84^{a}\pm0.44$	$1.17^{d}\pm0.13$	$3.56^{e}\pm3.78$	$16.21^{c}\pm1.11$
80	6	$11.04^{c}\pm0.67$	$1.27^{c}\pm0.11$	$10.00^{c}\pm6.63$	$11.74^{g}\pm1.62$
	12	$11.30^{b}\pm1.60$	$1.28^{c}\pm0.11$	$2.01^{f}\pm2.11$	$17.66^{b}\pm1.75$
	24	$10.83^{d}\pm0.72$	$1.32^{b}\pm0.15$	$0.90^{g}\pm1.04$	$18.26^{a}\pm0.52$
Control		$9.28^{g}\pm0.09$	$1.26^{cd}\pm0.16$	$99.48^{a}\pm0.00$	$72.27^{a}\pm0.01$
CV (%)		2.12	4.05	13.32	1.44
$LSD_{0.05}$		0.21	0.05	0.87	0.2

Note: SkTp: soaking temperature, SkTm: soaking time, CT: cooking time (minutes), SR: swelling ratio (mm/mm), ΔE: color change between parboiled and non-parboiled rice, values are mean±SD

Effects of steaming time and soaking temperature on cooking quality

Table 2 presents the interaction effect of soaking temperature and steaming time on cooking qualities. Cooking quality parameters were significantly (P<0.05) affected by the interaction of the factors. Generally, the cooking time increased as both the soaking temperature and steaming times increased. The minimum cooking times (9.52 and 9.31 minutes) were recorded at the combinations of the lowest (40°C) soaking temperature and shortest (15 and 25 minutes) steaming times. These values were statistically the same as the 9.28 minutes of the control sample. As the soaking temperature and steaming time rose, the cooking time of parboiled rice was extended. The interaction effect appeared to be balanced both factors exerting their influence on the cooking time. Ayenew *et al*. (2020) reported that the minimum cooking times of Ethiopian rice varieties were identified as 16-23 minutes for both *Ediget* and *Gumara* varieties when soaked at 40-80°C for 10-50 minutes.

The interaction of soaking temperature and steaming time significantly (P<0.05) affected the water uptake ratio of parboiled rice. The highest values (1.46 and 1.62) were of samples subjected to the combination of the lowest (40°C) soaking temperature and the two lower soaking times (15 and 25 minutes). At combinations of the higher soaking temperatures (60 and 80°C) and the three steaming times the values significantly dropped in some cases with no significant difference from the 0.98 of the non-parboiled rice. These findings are supported by the work of Chavan *et al*., l (2018) who showed that soaking at 85°C and steaming for 40 minutes significantly (P<0.05) improved the water uptake ratio to 2.96%.

The swelling ratio of parboiled rice was also significantly (P<0.05) affected by the interaction of the two factors. The values ranged between 1.17 and 1.42 varying randomly. The non-parboiled rice exhibited a value of 1.26.

The chalkiness of parboiled rice was significantly affected (P<0.05) by the interaction of soaking temperature and steaming time. The highest value (99.48) was of the control non-parboiled sample. Of the parboiled rice, the highest value (15.22%) was of the combination of the lowest soaking temperature (40°C) and shortest steaming time (15 minutes). The values decreased as the steaming time increased for all soaking temperatures and as the soaking temperature increased the chalkiness values dropped significantly. Thus the lowest value (0.68%) was of the combination of the highest (80°C) soaking temperature and longest (35 min) steaming time.

The parboiling process affected the overall color difference of the rice samples. The highest overall color value (16.79) was determined for samples treated by the lowest soaking temperature (40°C) and longest steaming time (35 minutes). The color difference value of parboiled rice in this study ranged from 10.54 to 16.79. Similar research work also showed that the color value for fresh parboiled rice samples was significantly (P<0.05) reduced to the non-parboiled rice (Nawaz *et al*., 2018).

Table 2: Effects of soaking temperature and steaming time on cooking quality parameters

SkTp (°C)	SmTm (minutes)	CT (minutes)	WUR	Swelling Ratio	Chalkiness (%)	Color (ΔE)
40	15	9.52^{f}±0.29	1.46^{b}±0.37	1.32^{b}±0.15	15.22^{b}±10.72	12.01^{f}±1.44
	25	9.31^{f}±0.79	1.62^{a}± 0.30	1.42^{a}±0.15	11.78^{d}±8.06	10.54^{g}±1.52
	35	10.14^{d}±1.10	1.20^{cd}±0.19	1.17^{d}±0.05	1.44^{hi}±1.13	16.79^{b}±2.06
60	15	10.54^{c}±1.08	1.01^{e}± 0.15	1.18^{cd}±0.15	12.67^{c}±3.61	14.55^{e}± 0.18
	25	11.25^{ab}±1.40	1.13^{de}±0.14	1.21^{cd}±0.12	6.00^{f}±4.66	14.66^{e}±3.39
	35	9.79^{e}±1.47	1.12^{de}± 0.20	1.17^{d}±0.15	2.22^{h}±1.98	15.84^{d}±1.64
80	15	10.46^{c}±1.13	1.08^{de}±0.10	1.30^{b}±0.15	7.11^{e}±6.09	14.56^{e}± 3.88
	25	11.25^{b}±0.92	1.19^{cd}± 0.18	1.23^{c}±0.12	5.12^{g}±6.52	16.52^{c}± 2.37
	35	11.46^{a}± 0.95	1.26^{c}±0.16	1.34^{b}±0.07	0.68^{i}±0.99	16.57^{c}± 3.39
Control		9.28^{f}±0.09	0.98^{e}±1.02	1.26^{c}±0.16	99.48^{a}±0.00	72.27^{a}±0.01
CV (%)		2.12	11.34	4.05	13.32	1.44
$LSD_{0.05}$		0.21	0.13	0.05	0.87	0.2

Note: SkTp: soaking temperature, SmTm: steaming time, CT: cooking time, WUR: water uptake ratio, and ΔE: the color difference between parboiled and non-parboiled rice, values are in mean±SD, means represented by the same letter are not significant

Effects of soaking and steaming times on Cooking Quality

Table 3 presents the data showing the interaction effects of soaking time and steaming time on the cooking qualities of parboiled rice. All parameters of cooking quality were affected by the interaction of these two factors except the water uptake ratio, which did not exhibit statistically significant differences. The shortest cooking times of the parboiled rice were 9.76, 9.66, and 9.85 minutes for samples with a steaming time of 15 minutes combined with soaking times of 6 and 12 hours, respectively, and for the sample treated with a combination of 12 minutes of soaking and 35 minutes of steaming. On the other hand, the longest cooking times (11.09, 10.96, and 11.00 minutes with no statistical difference among them) were recorded for combinations of 24-hour soaking time with all three (15, 25, and 35 minutes) steaming times, respectively. The control sample (non-parboiled rice) had the shortest (9.28 minutes) cooking time. Thus parboiling process led to prolonged cooking time for the *selam* rice variety.

The interaction of soaking and steaming times significantly (P<0.05) affected the swelling ratio. The values ranged from 1.17-1.32 with the highest values being 1.27, 1.28, 29, and 1.32, the majority belonging to the 6 hours of soaking time combined with all three steaming times. All swelling ratios of the parboiled rice were significantly greater than the 0.98 of the control sample showing that parboiling improves swelling of rice granules.

Table 3: Interaction effects of soaking and steaming time on cooking quality parameters

SkTm	SmTm	CT (min)	SR	Chalkiness (%)	Color (ΔE)
6	15	9.76^{d}± 0.53	1.27^{abc}±0.17	17.67^{b}±3.39	11.45^{h}±2.25
	25	10.56^{b}±1.55	1.32^{a}±0.21	15.33^{c}±4.00	10.84^{i}±2.01
	35	10.55^{b}±0.96	1.28^{abc}±0.07	2.56^{g}±1.81	14.75^{f}±2.07
12	15	9.66^{d}±0.61	1.26^{bc}±0.14	13.56^{d}±8.05	14.10^{g}±1.40
	25	10.29^{c}±1.58	1.29^{ab}±0.14	6.11^{e}±1.11	15.34^{e}±3.86
	35	9.85^{d}±1.97	1.17^{d}±0.13	1.46^{h}±0.50	15.98^{c}±2.36
24	15	11.09^{a}±1.08	1.26bc±0.17	3.78^{f}±1.20	15.57^{d}±2.28
	25	10.96^{a}±1.04	1.24^{bc}±0.12	1.46^{h}±0.37	15.54^{d}±2.38
	35	11.00^{a}±0.67	1.23^{c}±0.14	0.33^{i}±0.17	18.47^{b}±1.01
Control		9.28^{e}±0.09	0.98^{e}±1.02	99.48^{a}±0.16	72.27^{a}±0.00
CV (%)		2.12	4.05	13.32	1.44
$LSD^{0.05}$		0.21	0.05	0.87	0.2

Note: SkTm: soaking time (hour), SmTm: steaming time (min), CT: cooking time in minutes, SR: swelling ratio, (ΔE): overall color, values are in mean±SD

The percentage of chalkiness was also significantly (P<0.05) affected by the interaction of soaking and steaming times. It decreased the values from 17.67 to 0.33% as the combinations of factors were increased from 6 hours and 15 minutes to 24 hours and 35 minutes. The effect of the interaction of the two factors on chalkiness is balanced such that a reduction of the values is observed both within each soaking time and across the three steaming times. Regarding the color difference between the parboiled and non-parboiled rice significant (P<0.05) differences were observed attributed to the interaction of the two factors. The largest difference (18.47) was of the sample subjected to the combination of largest soaking time (24 hr) and longest steaming time (35 minutes). It appeared that the influence of the highest steaming time within the interaction is visible resulting in the highest value at each of the three soaking times. However, the interaction of the two lower steaming times (15 and 25 minutes) and the three soaking times did not show a visible trend in color difference values. The color value of the non-parboiled rice is 72.27.

Interaction Effects of Heat Treatment, Soaking Time, and Steaming Time on Cooking Qualities of Parboiled Rice

Effects of parboiling on cooking time

Table 4 presents the three-factor interaction effects of pre-heating, soaking time, and steaming time on the cooking qualities of rice. At the lowest soaking temperature (40ºC) samples subjected to the highest soaking (24 hr) and steaming (25 and 35 minutes) times showed relatively longest cooking times of 10.14 and 11.29 minutes. A similar trend was observed for a soaking temperature of 60ºC with cooking times of 11.81, 12.29, and 11.43 minutes for 15, 25, and 35 minutes of steaming times whereas at 80ºC soaking, this trend was noted for combinations of 12 hr soaking time and 25 and 35 min steaming times. The rest of the combinations of the three factors did not show any clear trend in the cooking times. Some combinations of the three factors had even resulted in cooking times shorter than that of the non-parboiled rice. For instance, cooking times of 8.13, 8.68, 9.05, 9.10 and 9.17 minutes had been observed.

A similar study that was done by Ayenew *et al*. (2020) reported that the minimum cooking time of *Gumara* and *Ediget*, domestic rice varieties, was found to be 16 minutes, which were recorded at 40°C and 10 minutes, respectively.

Effects of parboiling on swelling ratio

The interaction of these three factors also significantly affected (P<0.05) the swelling ratio. The records did not show any clear trend with some of the values being lower than the 2.26 of non-parboiled rice used as control while others exhibited higher values even up to 1.41 and 1.54. A similar study showed that the value of the swelling ratio of the *Gumara* variety ranged from 2.46 at a temperature of 40°C and steaming time of 10 minutes to 3.00 recorded at a soaking temperature of 80°C and 50 minutes of steaming time (Ayenew *et al*., 2020).

It was also mentioned that the swelling ratio of parboiled rice varied depending on the parboiling conditions and varieties (Nawaz *et al*., 2018).

Effects of Parboiling on Chalkiness of Rice

The data showing the degree of chalkiness of rice are given in Table 8. The result indicated that the chalkiness value significantly (P<0.05) decreased with an increase in soaking temperature, soaking time, and steaming time. For a given soaking temperature as the soaking time increased, chalkiness values decreased, and for each soaking time the chalkiness values decreased as the steaming time increased. Thus all three factors have a strong and balanced influence on the chalkiness of the rice grains. Samples subjected to a combination of the lowest soaking

temperature (40°C), short soaking times of 6 and 12 minutes) and short steaming time (15 and 25 minutes) resulted in statistically the highest (20.33, 22.00, and 22.67%) chalkiness value. This is because the level of gelatinization of the starches in the grain under this treatment combination is low. Rice starch gelatinization temperature is between 55 and 79°C. On the other hand, samples subjected to the highest soaking temperature (80°C), longest soaking time, and longest steaming time resulted in the lowest chalkiness value of 0.33%. The steaming times, 15, 25, and 35 minutes have played a significant role in reducing the chalkiness values since thermal treatment is responsible for gelatinizing the starch inside the rice kernels in the presence of water. Gelatinized starch allows more light through it changing the rice grain into more translucent and thus less chalky. Combinations of different intermediate values of the soaking temperature, soaking time, and steaming time resulted in intermediate chalkiness values (Saha, et al., 2021).

Generally, parboiling decreased the percentage of chalkiness from 99.48% of the control non-parboiled sample to 0.33% of the parboiled one. A similar study on the *Narica-4* rice variety showed that the percentage of chalkiness was decreased from 100% (control) to 0.13% when soaked at 70°C heating temperature 50 minutes of steaming time, and 80°C soaking temperature and 50 minutes of steaming time (Ayenew *et al*., 2020). Another study also argued that the opaque white appearance seen on the rice grain of milled rice was highly reduced by the parboiling process (Oli *et al*., 2014).

Effects of parboiling on a color value

The overall color value (ΔE) of parboiled ranged from 8.95 to 19.54. The highest color difference was found at the lowest temperature (40°C), highest soaking (24 hours), and highest steaming times (35 minutes). The least color difference (8.95) was recorded at a soaking temperature of 40°C, soaking time of 6 hours, and steaming time of 25 minutes (Table 8). A similar study conducted in this regard stated that the color of parboiled rice was found to be 25.8, which was recorded at the soaking temperature and time, and steaming time combination of 67.7°C, 13 hours, and 18 minutes, respectively (Ogunbiyi *et al*., 2018). According to the study by Srisang and Chungcharoen (2019), the percentages of whiteness for the parboiled rice showed a decreasing trend compared to the non-parboiled rice.

Table 4: Effects of three-way interaction of parboiling factors on cooking quality

SkTp	SkTm	SmTm	Cooking time(min)	Swelling Ratio	Chalkiness (%)	Color (ΔE)
	6	15	$9.46^{hij}\pm0.15$	$1.38^{bc}\pm0.16$	$22.00^{b}\pm1.00$	$10.18^{o}\pm0.00$
	6	25	$8.69^{m}\pm0.53$	$1.54^{a}\pm0.12$	$20.33^{b}\pm1.53$	$8.95^{q}\pm0.03$
	6	35	$10.09^{fg}\pm0.45$	$1.21^{ghij}\pm0.05$	$2.00^{gh}\pm1.00$	$15.59^{h}\pm0.04$
	12	15	$9.37^{ijkl}\pm0.21$	$1.27^{b}\pm0.16$	$22.67^{b}\pm1.53$	$12.43^{m}\pm0.10$
40	12	25	$9.10^{kl}\pm0.52$	$1.41^{efg}\pm0.13$	$13.00^{de}\pm1.00$	$10.26^{o}\pm0.12$
	12	35	$9.05^{l}\pm0.53$	$1.14^{jk}\pm0.04$	$2.00^{gh}\pm1.00$	$15.25^{i}\pm0.04$
	24	15	$9.72^{hi}\pm0.43$	$1.29^{defg}\pm0.16$	$1.00^{h}\pm1.00$	$13.43^{l}\pm0.09$
	24	25	$10.14^{fg}\pm0.50$	$1.30^{defg}\pm0.12$	$2.00^{gh}\pm1.00$	$12.42^{m}\pm0.11$
	24	35	$11.29^{de}\pm0.77$	$1.18^{hijk}\pm0.04$	$0.33^{h}\pm0.58$	$19.54^{b}\pm0.07$
	6	15	$9.38^{ijkl}\pm0.22$	$1.17^{ijk}\pm0.16$	$16.00^{c}\pm1.00$	$14.43^{k}\pm0.10$
	6	25	$12.05^{ab}\pm0.49$	$1.14^{jk}\pm0.12$	$12.00^{e}\pm1.00$	$10.15^{o}\pm0.07$
	6	35	$9.82^{gh}\pm0.42$	$1.35^{bcde}\pm0.04$	$4.33^{g}\pm1.53$	$16.59^{g}\pm0.36$
	12	15	$10.45^{f}\pm0.14$	$1.24^{ghi}\pm0.17$	$13.67^{cde}\pm1.53$	$14.46^{jk}\pm0.04$
60	12	25	$9.43^{ijk}\pm0.12$	$1.22^{ghij}\pm0.12$	$4.00^{g}\pm1.00$	$17.20^{f}\pm0.01$
	12	35	$8.13^{n}\pm0.49$	$1.04^{l}\pm0.04$	$2.00^{gh}\pm1.00$	$13.70^{l}\pm0.05$
	24	15	$11.81^{b}\pm0.42$	$1.14^{jk}\pm0.17$	$8.33^{f}\pm1.53$	$14.78^{j}\pm0.09$
	24	25	$12.29^{a}\pm0.14$	$1.26^{fgh}\pm0.12$	$2.00^{gh}\pm1.00$	$16.64^{g}\pm0.03$
	24	35	$11.43^{cd}\pm0.17$	$1.11^{kl}\pm0.04$	$0.33^{h}\pm0.58$	$17.23^{f}\pm0.02$
	6	15	$10.45^{f}\pm0.11$	$1.26^{fg}\pm0.16$	$15.00^{cd}\pm1.00$	$9.73^{p}\pm0.08$
	6	25	$10.94^{f}\pm0.61$	$1.27^{efg}\pm0.13$	$13.67^{cde}\pm1.53$	$13.42^{l}\pm0.04$
	6	35	$11.74^{bc}\pm0.34$	$1.28^{defg}\pm0.05$	$1.33^{h}\pm1.53$	$12.05^{n}\pm0.04$
	12	15	$9.17^{jkl}\pm0.15$	1.27efg±0.16	$4.33^{g}\pm1.53$	$15.43^{hi}\pm0.09$
80	12	25	$12.35^{a}\pm0.23$	$1.24^{ghi}\pm0.12$	$1.33^{h}\pm1.53$	$18.56^{d}\pm0.01$
	12	35	$12.37^{a}\pm0.22$	$1.32^{cdef}\pm0.05$	$0.37^{h}\pm0.55$	$18.99^{c}\pm0.05$
	24	15	$11.75^{bc}\pm0.35$	$1.36^{bcd}\pm0.16$	$2.00^{gh}\pm1.00$	$18.52^{d}\pm0.01$
	24	25	$10.45^{f}\pm0.12$	$1.18^{hijk}\pm0.12$	$0.37^{h}\pm0.55$	$17.58^{e}\pm0.19$
	24	35	$10.28^{f}\pm0.05$	$1.41^{b}\pm0.05$	$0.33^{h}\pm0.58$	$18.67^{cd}\pm0.04$
Control			$9.28^{jkl}\pm0.09$	$1.26^{fg}\pm0.16$	$99.48^{a}\pm0.00$	$72.27^{a}\pm0.01$
CV (%)			3.59	9.90	11.01	1.22
$LSD_{0.05}$			0.61	0.20	1.84	0.34

Note: SkTp: soaking temperature (°C), SkTm: soaking time (hours), SmTm: steaming time (minutes), means represented by the same letter are not significant, values are in mean±SD

Conclusions

Rice is becoming one of the most valuable crop commodi-ties in Ethiopia. Rice can be consumed directly by cooking brown or white processed rice. But the domestic rice lacks the desired milling and cooking qualities. This study was launched to enhance the quality of rice kernels by examining treatment combinations during the parboiling process. The parboiling method enhanced the rice's physical characteristics. The length of parboiled milled rice increased to 5.33-6.84 mm compared to 4.57 mm for non-parboiled. Cooking factors included cooking duration, absorption of water ratio, and swelling ratio. The cooking time for par-boiled milled rice varied from 8.13 to 12.35 minutes. The swelling ratio was highest (1.54) at a soaking temperature of 40°C, a soaking period of six hours, and a steaming time of 25 minutes. The chalkiness of parboiled rice was signifi-cantly decreased to 0.33%. The color distinction between parboiled grains and non-treated rice grew with the duration and before treatment temperature of soaking and steaming.

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Authors contribution

Melese Ageze contributed to proposal writing, conducting the experiment, data collection, data analysis, and final paper writing. Getachew Neme contributed to proposal writing, revising, and interpretation. Solomon Abera contributed to methodology and design setup, final paper writing, and interpretation and approval.

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There is no potential conflict of interest among the author(s).

Data repository Statement

This manuscript is an original research study. We used original data as stated in the manuscript document. The data is available in our hosting institute document data base (the Ethiopian Institute Agricultural Research)

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The Effect of Macroeconomic Variables on Agricultural Production in Türkiye

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Abstract

Agricultural production in the Turkish economy is strongly influenced by macroeconomic variables. Macroeconomic indicators such as inflation, interest rates, exchange rates and credit policies are among the basic elements that determine the production volume in the agricultural sector. The aim of this study is to examine the effects of macroeconomic factors on agricultural production in Turkey. In the study, the effects of the identified macroeconomic variables on agricultural production were evaluated using time series analysis. The data were obtained and analysed from the Turkish Statistical Institute (TURKSTAT), the Central Bank and other official institutions. The results show that exchange rate fluctuations have an impact on production, that changes in interest rates affect agricultural investments and that public support has a significant impact on production levels in the sector. This study aims to contribute to the development of policies that support sustainable growth in the agricultural sector by proposing solutions to better understand the impact of macroeconomic policies on agricultural production.

Key Words: *Agricultural Production, Macroeconomics, Inflation, Interest Rates, Exchange Rates, Agricultural Policies*

Türkiye'de Makro Ekonomik Değişkenlerin Tarımsal Üretim Üzerine Etkisi

Özet

Türkiye ekonomisinde tarımsal üretim, makro ekonomik değişkenlerden yoğun bir şekilde etkilenmektedir. Enflasyon, faiz oranları, döviz kuru ve kredi politikaları gibi makroekonomik göstergeler, tarım sektöründe üretim hacmini belirleyen temel unsurlar arasında yer almaktadır. Bu çalışma, Türkiye'de makro ekonomik faktörlerin tarımsal üretim üzerindeki etkisini incelemeyi amaçlamaktadır. Araştırmada, zaman serisi analizleri kullanılarak, belirlenen makro ekonomik değişkenlerin tarımsal üretim üzerindeki etkileri değerlendirilmiştir. Veriler, Türkiye İstatistik Kurumu (TÜİK), Merkez Bankası ve diğer resmî kurumlardan temin edilerek analiz edilmiştir. Elde edilen bulgular, döviz kurlarındaki dalgalanmaların üretim üzerinde etkili olduğu, faiz oranlarındaki değişikliğin tarımsal yatırımları etkilediğini ve kamu desteklerinin sektörde üretim seviyesini önemli ölçüde şekillendirdiğini ortaya koymaktadır. Bu çalışma, makro ekonomik politikaların tarımsal üretime olan etkilerini daha iyi anlamaya yönelik çözüm önerileri sunarak, tarım sektöründe sürdürülebilir büyümeyi destekleyici politikaların geliştirilmesine katkı sağlamayı hedeflemektedir.

Anahtar Kelimeler: *Tarımsal Üretim, Makro Ekonomi, Enflasyon, Faiz Oranları, Döviz Kuru, Tarım Politikaları*

Giriş

Türkiye'de tarım sektörü, gayri safi milli hasılayı (GSYİH), istihdam yapılarını, gıda güvenliğini ve ihracat performansını etkileyerek ulusal ekonomide çok yönlü bir rol üstlenmektedir. Türkiye'de tarım sektörü, GSYİH'ye katkısı açısından, genel ekonomik yapı için kritik önemini korumasına rağmen, göreli çıktıda düşüş yaşamıştır. Son yirmi yılda uygulanan yapısal uyum programları, ulusal ekonomik öncelikleri tarımdan imalat ve hizmetlere doğru yeniden yönlendirmiş ve böylece ülkenin katma değerindeki tarımın payını azaltmıştır (Günçavdı vd., 2013). Ek olarak, büyüyen ekonomilerdeki yapısal dönüşümü inceleyen araştırmalar, genel tarımsal GSYİH ve istihdam payları azalırken, tarımsal emtialar ulusal ihracattaki göreli varlığının önemli kalabileceğini vurgulamaktadır (Anderson & Ponnusamy, 2022). Bu bulgular, tarımın GSYİH'ye doğrudan katkısının azalmasına rağmen, performansının hala daha geniş ekonomik göstergelerle, özellikle ihracatla iç içe olduğunu ve kırsal ekonomik kalkınma için bir temel oluşturmaya devam ettiğini göstermektedir (Günçavdı vd., 2013; , Anderson & Ponnusamy, 2022).

Tarım sektöründeki istihdam, değişen dinamiklere rağmen Türkiye işgücü piyasasının temel taşlarından biri olmaya devam etmektedir. Yapılan çalışmalar, tarımın ülke işgücünün yaklaşık %20'sini istihdam ettiğini, bu değişimin farklı ölçüm yaklaşımlarına ve gayri resmi işgücünün dahil edilmesine atfedildiğini bildirmektedir (Günçavdı vd., 2013; Aksüt ve Eren, 2024). Sektör, nüfusun önemli bir bölümüne istihdam sağlamakla kalmayıp aynı zamanda önemli miktarda kayıt dışı işgücünü de içermektedir (Bulut vd., 2023).

Türkiye'de gıda güvenliği, iç tarımsal üretimle karmaşık bir şekilde bağlantılıdır. Tarımın istikrarlı bir gıda tedariki sağlamadaki rolü, istihdam, gelir yaratma ve yerelleştirilmiş üretim ağları aracılığıyla bağlantılar kurarak kritik bir güvenlik ağı görevi görür (Diaz-Bonilla, 2015). Politika analizleri, tarımsal üretimin yarattığı büyüme çarpanlarının, özellikle işgücünün yüksek oranlarının tarımsal faaliyetlere bağımlı olduğu bağlamlarda, yoksulluğun azaltılmasına ve gıda güvenliğinin teşvik edilmesine önemli ölçüde katkıda bulunduğunu göstermiştir. İhracat açısından, Türk tarımı küresel piyasa baskıları ışığında hem zorluklarla hem de fırsatlarla karşı karşıya kalmıştır. Ampirik kanıtlar, tarımsal destek politikalarının yıllar içinde azaldığını ve tarımsal emtia fiyatlarının uluslararası seviyelere doğru eğilim göstermesine yol açtığını göstermektedir (Dağdemir, 2014). Aynı zamanda, tarımın GSYİH ve istihdamdaki payının azalmasıyla karakterize edilen tarımdan uzaklaşma olgusu, tarımsal ürünlerin ihracat potansiyelinde mutlaka bir düşüş anlamına gelmez (Anderson & Ponnusamy, 2022). Yapısal dönüşümün dinamiklerine odaklanan çalışmalar, tarım sektörü küresel piyasa standartlarına etkili bir şekilde uyum sağladığında ulusal ihracatta önemli bir paya sahip olduğunu ve ekonomik dayanıklılık ve döviz kazançlarındaki rolünü güçlendirdiğini vurgulamaktadır (Anderson & Ponnusamy, 2022).

Bu kapsamda, tarımsal üretimin makroekonomik faktörlerden etkilenme durumu önemli bir çalışma konusu haline gelmektedir. Döviz kuru, gösterge faiz oranı, üretici fiyat endeksi ve tarımsal kredi hacmi gibi değişkenlerin tarımsal üretim üzerindeki etkisini incelemenin politika yapıcılar açısından stratejik karar almayı kolaylaştıracaktır.

Kavramsal Çerçeve

Tarımsal Kredilerin Üretime Etkisi

Tarımsal krediler, üretimi modernize etmenin, girdi erişimini geliştirmenin ve likidite kısıtlamalarını hafifletmenin temel belirleyicisidir. Yapılan çalışmalar, tarımsal kredinin mevcudiyetinin girdilere, teknolojiye ve verimli kaynak tahsisine yatırımı kolaylaştırdığını göstermektedir (Kaya & Kadanalı, 2021; Akdemir vd., 2021)

Tarımsal krediler, üreticilerin girdi temini ve teknolojilerin benimsemesini engelleyen finansal kısıtları hafifleterek teknik verimliliği ve genel üretim seviyelerini artırmaktadır (Sekyi vd., 2020; Sial vd., 2011; Bahşi ve Çetin, 2020). Birçok durumda, kredi enjeksiyonu, fazla üretimin sektöre yeniden yatırılabilmesi ve inovasyonu ve pazar katılımını daha da teşvik edebilmesi nedeniyle tarımın daha fazla ticarileşmesiyle ilişkilendirilmiştir (Sekyi vd., 2020; Misra vd., 2016; Magazzino vd., 2021). Teknolojik ve girdi yönlerinin ötesinde, tarımsal kredi, tarım sektöründe daha iyi risk yönetimi ve daha verimli kaynak tahsisini teşvik ederek daha geniş ekonomik çevreyi etkiler. Tarım sektörünün ulusal GSYİH ve istihdamın önemli bir oranını temsil ettiği birçok gelişmekte olan ekonomide, kredi müdahaleleri çiftçilerin üretim ve piyasa talepleri arasındaki boşluğu kapatmasını sağlamada temel olmuştur (Sekyi vd., 2020; Ammani, 2012; Magazzino vd., 2021).

Faiz Oranı - Tarımsal Üretim ilişkisi

Faiz oranlarının tarımsal yatırımlardaki rolü çok yönlüdür ve hem sermayenin doğrudan maliyeti hem de yatırım planlamasında bulunan daha geniş belirsizlik yoluyla kararları etkiler. Optimum bir faiz oranı ortamı, yalnızca tarımsal girdilerin modernizasyonu için giriş engelini düşürmekle kalmaz, aynı zamanda belirsizliği de azaltır ve böylece tarıma sürdürülebilir yatırım yapılmasını teşvik eder. Bu da, sektör içinde artan üretkenliği ve uzun vadeli büyümeyi teşvik eder (Koželský vd., 2024; Dias & Shackleton, 2009; Abdulah & Latif, 2023; Hmzah, 2017).

Döviz Kuru – Tarımsal Üretim İlişkisi

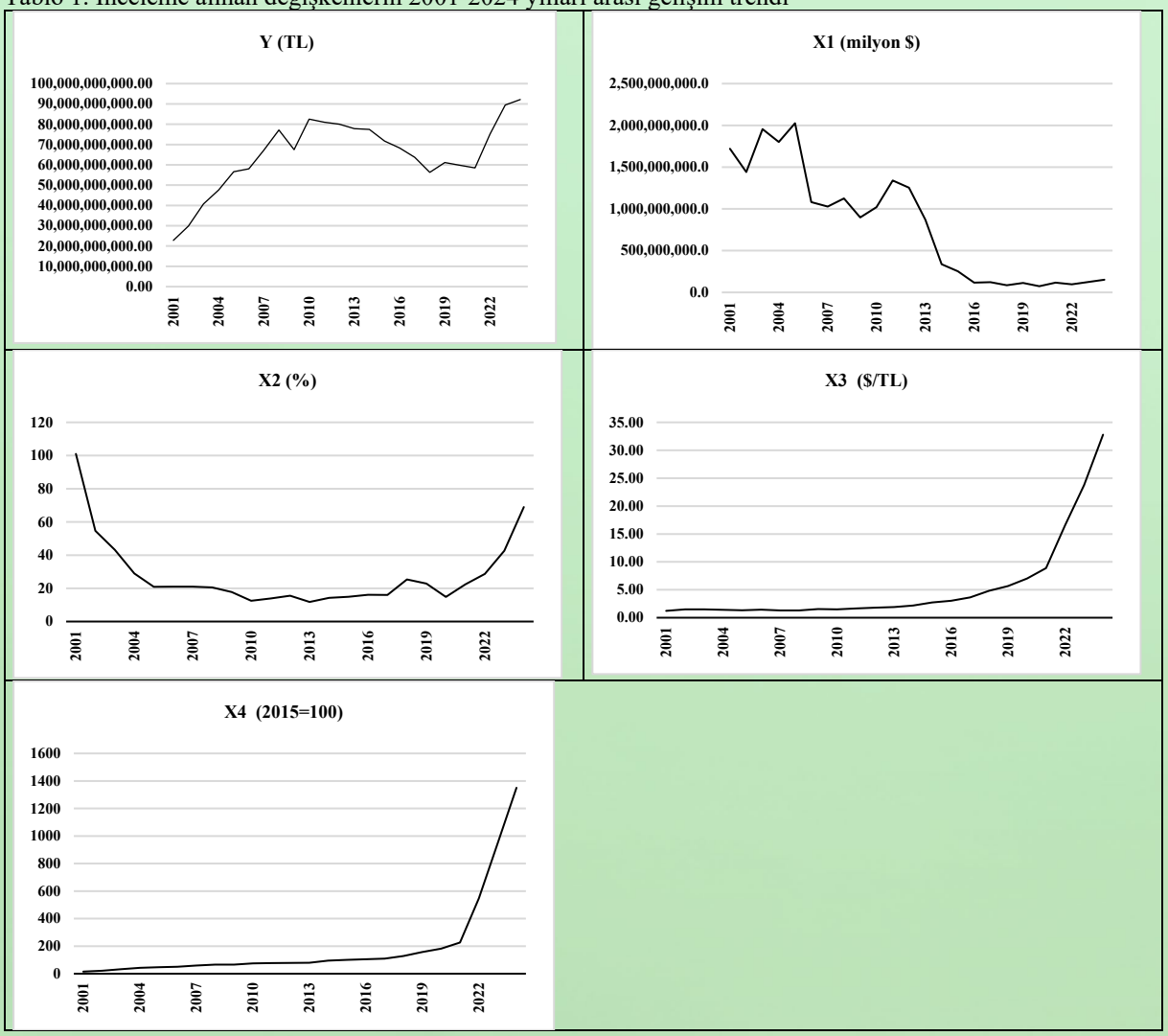
Döviz kurları, ithal girdilerin (örneğin gübre, yakıt, makine, böcek ilacı) satın alındığı fiyatı etkilemenin yanı sıra yerli girdilerin rekabet gücünü etkileyerek tarımsal girdi maliyetlerinin şekillenmesinde merkezi bir rol oynar. Yapılan çalışmalar, döviz kuru dinamiklerinin tarımsal girdi maliyetlerinin önemli bir belirleyicisi olduğu görüşünü desteklemektedir. İthal girdilerin fiyatları üzerindeki doğrudan etkiler ve küresel enerji fiyatları ve daha geniş makroekonomik oynaklığın aracılık ettiği dolaylı etkiler yoluyla döviz kuru dalgalanmaları, tarımsal üreticilerin karşı karşıya kaldığı maliyet baskılarına önemli ölçüde katkıda bulunmaktadır. Bu nedenle, etkili döviz kuru yönetimi ve para politikası, girdi maliyeti oynaklığını azaltmak ve tarımsal üretimin rekabet gücünü ve sürdürülebilirliğini artırmak için değerli araçlar olarak hizmet edebilir (Johnson vd., 2011; Kim, 2015; Harri vd., 2009; Adejumo, 2020; Javadi vd., 2024; Damba vd., 2019) .

Üretici Fiyatları Endeksi – Tarımsal Üretim ilişkisi

Üretici fiyat endeksi, yalnızca fiyat istatistiklerini değil aynı zamanda piyasa talebi, girdi maliyeti dinamikleri ve dış ekonomik şoklardan etkilenen daha geniş bir üretim ekosistemini temsil etmektedir. İstikrarlı veya iyileşen girdi maliyeti koşullarıyla uyumlu olduğunda artan bir ÜFE, gelişen bir tarımsal üretim ortamını gösterebilir. Buna karşılık, artan ÜFE ile artan girdi maliyetleri arasındaki tutarsızlıklar, üreticilerin karlılığı için potansiyel zorluklara işaret ediyor olabilir. ÜFE'lerin üretim sonuçlarını tahmin etmek ve tarımsal politika ayarlamalarına

rehberlik etmek için stratejik araçlar olarak nasıl işlev görebileceğine dair önemli öngörüler sunabilmektedir (Nwaubani vd., 2020; Vargas vd., 2023; Dhakal, 2020). Bu araştırma kapsamında incelemeye alınan değişkenlere ilişkin 2001-2024 yılları arası gelişim trendleri Tablo 1' de verilmiştir.

Tablo 1. İnceleme alınan değişkenlerin 2001-2024 yılları arası gelişim trendi



Tablo 1 incelendiğinde, tarımsal GSUD genel olarak uzun vadede pozitif trend göstermiştir, fakat ekonomik krizler ve pandemi gibi dönemlerde şoklardan etkilenmiş olarak değerlendirilebilir. Tarımsal kredi hacmi ekonomik şoklara duyarlı bir değişken olarak değerlendirilebileceğinden kriz ve pandemi dönemlerinde dalgalanma göstermiş, fakat toparlanma dönemlerinde hızlı şekilde artış yönlü hareket etmiştir. Gösterge faiz zaman içinde yavaş ama istikrarlı bir şekilde büyümüş, ani dalgalanmalardan fazla etkilenmemiştir. Bu trend gösterge faiz için temel bir değişken olabileceğine işaret etmektedir. Dolar kuru kriz ve pandemi gibi şoklara duyarlı bir değişkendir ancak toparlanma dönemlerinde çok güçlü bir büyüme potansiyeli göstermektedir. Üretici fiyat endeksi ise genel olarak stabil ve orta vadede büyüme göstermiştir.

Materyal Yöntem

Söz konusu değişkenler kullanılarak yapısal kırılmalı birim kök testi ve sonrasında kantil regresyon analiziyle değişkenlerin tarımsal GSUD üzerindeki etkisi açıklanmıştır.

Zaman serisinin durağan olup olmadığını ve seride yapısal kırılmaların varlığını test etmek amacıyla ADF Breakpoint Unit Root Testi kullanılmıştır. Klasik Augmented Dickey-Fuller (ADF) testi, serinin tüm dönem boyunca aynı yapıyı koruduğunu varsaymakta ve olası yapısal kırılmaları dikkate almamaktadır. Ancak ekonomik ve finansal zaman serilerinde çeşitli şoklar nedeniyle yapısal değişiklikler meydana gelebilmektedir. Bu nedenle, seride bir kırılma noktasına izin veren ADF Breakpoint testi tercih edilmiştir. Test sürecinde kırılma noktası içsel olarak (endogenous) belirlenmektedir. Yani, veri setindeki en uygun kırılma noktası veri tarafından belirlenir, önceden dışsal bir şekilde seçilmez. Kırılma zamanlaması, genellikle test istatistiğini en küçük yapan tarih olarak tespit edilir.

Tablo 2. Değişkenler ve veri kaynakları

Değişken açıklaması	Sembol	Veri kaynağı
Tarımsal GSUD	Y	FAOSTAT
Tarımsal Kredi Hacmi	X_1	FAOSTAT
Gösterge Faiz	X_2	TC Merkez Bankası
Yıl ortası Dolar/TL kuru	X_3	TC Merkez Bankası
Üretici fiyat endeksi (2015=100)	X_4	TUIK

Veriler 2001-2024 yılları arası yıllık seri biçiminde kullanılmıştır. Tablo incelendiğinde, Y, X1, X2, X3, X4 sembolleri sırasıyla Tarımsal GSUD, Tarımsal Kredi Hacmi, Gösterge Faiz, Dolar/TL kuru ve Üretici fiyat endeksi (2015=100) ni temsil etmektedir. Veri seti 2001-2024 yılları arasını kapsamakta ve yıllık seri olarak incelenmeye alınmıştır.

Birim kök testi sonuçları değerlendirildikten sonra durağan serilerle kantil regresyon analizi yapılmıştır. Bağımlı değişkenin koşullu dağılımının farklı noktalarında (kantillerinde) açıklayıcı değişkenlerin etkisini analiz etmek amacıyla kantil regresyon yöntemi kullanılmaktadır. Klasik doğrusal regresyon yöntemleri (OLS) yalnızca ortalamaya odaklanırken, kantil regresyon modeli bağımlı değişkenin çeşitli dağılım noktalarında (örneğin medyan, alt veya üst çeyrekler) ilişkilerin farklılık gösterip göstermediğini incelemeye olanak tanımaktadır (Koenker ve Bassett, 1978).

Kantil regresyon modeli, aşağıdaki genel formda ifade edilir:
$Qy(\tau|X) = X\beta(\tau)$
Burada:
-$Qy(\tau|X)$, bağımlı değişkenin τ kantili koşullu tahminini temsil eder.
-X, açıklayıcı değişkenler matrisini,
-$\beta(\tau)$, τ kantiline özgü regresyon katsayılarını göstermektedir.

Kantil regresyon analizi hata terimlerinin pozitif ve negatif yönlerde farklı ağırlıklandırılmasını sağlar, böylece model değişkenliğin farklı bölümlerinde daha esnek bir şekilde tahmin yapabilir. Çalışmada, farklı kantil düzeylerinde (τ = 0.25, 0.50, 0.75) regresyon tahminleri gerçekleştirilmiş ve katsayıların değişimi incelenmiştir. Böylece, değişkenler arasındaki ilişkinin sadece ortalamada değil, dağılımın farklı bölümlerinde nasıl farklılaştığı ortaya konmuştur. Model doğrulama sürecinde pseudo R-kare değerleri ve Wald testi sonuçları dikkate alınmıştır.

Araştırma Bulguları

Araştırmada incelemeye alınan değişkenler için yapılan yapısal kırılmalı ADF birim kök testi Tablo 3' de verilmiştir. Tüm değişkenler I(1) yani birinci farkta durağan. Bu, serilerin seviye değerlerinde durağan olmadığını, ancak farkları alındığında durağanlaştığını göstermektedir. Serilerde yapısal kırılmalar özellikle 2020–2021 dönemlerinde yoğunlaşmaktadır. Bu COVID-19, kur şokları gibi olaylarla ilişkilendirilebilir.

Tablo 3. Birim kök testi sonuçları (ADF Breakpoint Unit Root Test)

Değişkenler	I(0)	I(1)	Breakpoint date
Y	-3,3865	-4,7177***	2021
X_1	-3,2256	-7,5920*	2013
X_2	-3,0311	-7,1764*	2020
X_3	-0,3108	-8,5046*	2021
X_4	-2,9481	-7,2545*	2021

Tablo 4. Kantil Regresyon Analizi Sonuçları

Bağımlı değişken: Y	0,25Q	0,50Q	0,75Q
X_1	0,0362 (0,0410)	0,0348 (0,0342)	0,0356 (0,0320)
X_2	-0,0957 (0,0672)	-0,1166*** (0,0606)	-0,1138** (0,0563)
X_3	-0,5755* (0,1302)	-0,5733* (0,1440)	-0,6582* (0,1904)
X_4	0,7652* (0,0874)	0,7209* (0,0194)	0,7506* (0,1188)
Diagnostik Tests	Pseudo-R^2:0,68 Prob:0,0000 Wald: 2,0976 Ramsey Reset: 1,05	Pseudo-R^2:0,75 Prob:0,0000 Wald: 2,0976 Ramsey Reset: 1,55	Pseudo-R^2:0,79 Prob:0,0000 Wald: 2,0976 Ramsey Reset: 2,62

Modelin genel geçerliliği, yüksek düzeydeki Pseudo R^2 değerleri ile desteklenmektedir. Ayrıca, Ramsey RESET testi değerlerinin düşük çıkması, modelde anlamlı bir spesifikasyon hatasına işaret etmediğini göstermektedir. Wald testi sonuçlarına göre, değişkenlerin kantiller arasında istatistiksel olarak anlamlı farklılık göstermediği belirlenmiştir. Bu da modelin genel yapısının kantil düzeylerinde tutarlı olduğunu ortaya koymaktadır. Birim kök testleri ve regresyon uyum kriterleri çerçevesinde, modelin yapısal sorunlara sahip olmadığı ve güvenilir sonuçlar sunduğu anlaşılmaktadır.

Kantil regresyon analizi sonuçları, tarımsal kredi hacminin tüm kantillerde pozitif bir ilişki gösterdiğini fakat bu ilişkinin istatistiksel olarak anlamlı olmadığını ortaya koymaktadır. Bu sonuç, kredi kullanımın tarımsal üretimi artırıcı yönde eğilim taşısa da söz konusu etkinin güçlü ve güvenilir düzeyde istatistiki anlamlılık bulmadığını göstermektedir. Faiz oranı, tüm kantil düzeylerinde tarımsal üretim ile negatif yönlü ve orta yüksek düzeyde anlamlı bir ilişki içerisindedir. Özellikle medyan (Q0.50) ve üst orta (Q0.75) kantillerde bu ilişkinin istatistiksel olarak anlamlı bulunması, faiz oranlarındaki artışın özellikle orta ve yüksek üretim düzeyine sahip gruplarda tarımsal üretimi olumsuz etkilediğini ortaya koymaktadır. Döviz kuru, üç kantilin tamamında tarımsal üretim ile yüksek düzeyde negatif bir ilişki olduğunu ve bu ilişkinin istatistiki olarak anlamlı olduğu tespit edilmiştir. Bu sonuç, kur artışlarının özellikle ithal girdilere olan bağımlılık nedeniyle üretim maliyetlerini artırarak tarımsal üretimi olumsuz yönde etkilediğini göstermektedir. Üretici fiyat endeksi (ÜFE) tüm kantil düzeylerinde pozitif ve anlamlı ilişki sunmuştur. ÜFE'nin pozitif etkisi, tarımsal üretimin aynı zamanda fiyatlara da yansımasıyla ilgili olabilir.

Sonuç ve Öneriler

Bu çalışma Türkiye'de tarımsal üretimin başlıca makroekonomik göstergeler ile olan ilişkisini incelemeyi amaçlamıştır. Çalışma sonuçları, tarımsal üretimin döviz kuru ve faiz oranlarındaki değişimlere karşı oldukça hassas olduğunu ortaya koymaktadır. Bu sonuç literatürle ile paralellik göstermektedir. Ochalibe vd, (2019) ve Eniekezimene vd. (2023) çalışmalarında, döviz kurundaki olumlu bir değişimin tarımsal üretim üzerinde olumlu bir etkiye sahip olduğunu, faiz oranlarındaki artışların ise daha yüksek borçlanma maliyetleri yoluyla üretimi baskılama eğiliminde olduğunu bildirmektedir. Döviz kuru artışının tüm kantillerde negatif ve istatistiki olarak anlamlı olması, tarımsal üretimin ithal girdilere bağımlılık düzeyinin yüksek olduğunu göstermektedir. Benzer şekilde faiz oranlarındaki artışın orta ve yüksek düzeylerinde üretimi anlamlı bir şekilde baskılaması, finansman maliyetlerinin bu gruplarda üretim kararlarını etkilediğini ortaya koymaktadır. Ogbuabor vd.(2020), faiz oranlarını etkileyen parasal politikanın, sermaye maliyetini değiştirerek tarım üzerinde yaygın bir etki uyguladığını ve böylece hem kısa hem de uzun vadeli üretim kararlarını etkilediğini ifade etmişlerdir.

Tarımsal kredi hacminin pozitif ilişkisine karşın istatistiki olarak zayıf etkisi, kredilerin üreticilerin ihtiyaçlarına etkin bir şekilde yanıt vermediğini ortaya koymaktadır. Benzer sonuçlar, Narayanan (2016) ve Alabi vd., (2023) araştırmalarında da mevcuttur. Bu sonuç, kredi sistemlerinde reformist yaklaşımlara ihtiyaç olduğunu göstermektedir. Bununla birlikte ÜFE ile tarımsal üretim arasında pozitif ve istatistiki olarak anlamlı ilişkisi bulunmuştur. Ancak teorik olarak üretici fiyatlarındaki artışın üretim maliyetlerini yükselterek, üretimi azaltması beklenmektedir. Bu durum, ÜFE artışlarının üreticiler tarafından gelecek dönem gelir beklentilerine olumlu yönde şekillenmesiyle açıklanabilir. Ayrıca devlet destekleri ve ürün fiyatlarındaki artışın girdi maliyetlerini telafi edici düzeyde olması da üretim kararlarının pozitif yönde etkilenmesine neden olmuş olabilir. Teoriğe ters olarak elde edilen sonucu destekleyen birçok çalışma da bulunmaktadır (Xie & Wang, 2017; Dhakal, 2020)

Elde edilen bulgular ışığında Türkiye tarımsal üretiminde üretim değerine yönelik gelişmelerin istikrarlı bir şekilde devam etmesi için bazı öneriler ortaya koyulabilir. İthal girdilere (gübre, mazot, tohum, ilaç) bağımlılığı azaltmak için yerli üretimi teşvik eden politikalar geliştirilebilir. Son yıllarda kamuoyuna da yansıyan benzer uygulamalar görülse de henüz serbest piyasa koşullarında etkisinin görülmediği ifade edilebilir. Diğer taraftan mevcut destekleme sistemi içerisinde tarım için kur bazlı sübvansiyonlar uygulanabilir. Örneğin, doğru, etkili ve dengeli bir planlamayla kurdaki ani artışlara karşı çiftçiye fiyat farkı ödemesi yapılabilir. Tarımsal girdi piyasalarında dövizle yapılan sözleşmelerin TL'ye çevrilmesi teşvik edilmesi de kur şoklarına karşı alınabilecek diğer bir önlem olarak düşünülebilir. Tarıma yönelik özel döviz kuru sigortası ürünleri de diğer bir alternatif olarak geliştirilebilir. Tarım sektörüne özel düşük faizli kredi uygulamaları daha da yaygınlaştırılabilir. Faiz destekli tarım kredileri (örneğin Ziraat Bankası kanalıyla) üreticilerin erişimine daha açık hale getirilerek yıllık değil mevsimlik ödeme planlarına uygun faiz sistemleri oluşturulup (hasat dönemine göre uyarlanmış krediler) hedef, üretim ve yerindelik esasları dikkatli bir şekilde izlenebilir. Bu süreçte yatırımların (sera, teknoloji, sulama sistemleri gibi) yönlendirilmesi kamu erki eliyle kontrol altında sıkı önlemlerle takip edilebilir. Ek olarak, üreticinin finansal okuryazarlık eğitimi ve bilgi düzeyine yönelik yayım çalışmaları kredi kullanım verimliliği sürecine olumlu katkı sağlayabilir. Bunun sağlanabilmesi adına teknik danışmanlık sisteminin geliştirilmesi önemli görülmektedir. Üretici fiyat endeksindeki artış ise, maliyetleri temsil etmesi bakımından üretici fiyatlarına doğrudan yansımaktadır. Enflasyon sorununun ilk aşaması olarak değerlendirilen ÜFE artışları ekonomik büyüklük olarak piyasaya yansıdığından tarımsal GSÜD arttırıcı bir etkiye sahip olabilir. Ancak, oluşan yüksek fiyatlar üreticinin üretim kararları ve üretim motivasyonu üzerinde olumlu etki oluşturmakla birlikte enflasyonla mücadele kapsamında dikkatle izlenmesi önerilmektedir.

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The Effects of the Russia-Ukraine War on Foreign Dependency and Fragility in Sunflower Production in Türkiye

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Abstract

The Russia-Ukraine war is having a profound effects on global food and agricultural markets and represents a significant risk factor for countries like Turkey that are dependent on sunflower oil imports. Turkey meets a large part of its sunflower oil needs from Ukraine and Russia, and there have been serious disruptions in this supply chain due to the war. The aim of this study is to assess the effects of the Russian-Ukrainian war on sunflower production, import dependency and vulnerability of the sector in Turkey. In this context, pre- and post-war import data, price fluctuations and changes in domestic production capacities in Turkey were analyzed and policy recommendations to reduce the sector's foreign dependency were discussed. The results show that the supply of sunflower oil in Turkey fluctuated significantly due to the war, prices increased and domestic production was insufficient. Therefore, it is recommended to support domestic production, develop strategies to increase supply diversity and make long-term planning in agricultural policies to reduce external dependence on sunflower oil imports.

Key Words: *Sunflower Production, Foreign Dependency, Russia-Ukraine War, Agricultural Policies, Food Security*

Rusya-Ukrayna Savaşının Türkiye'de Ayçiçeği Üretiminde Dışa Bağımlılık ve Kırılganlık Üzerine Etkileri

Özet

Rusya-Ukrayna savaşı, küresel gıda ve tarım piyasaları üzerinde derin etkiler yaratmış olup, Türkiye gibi ayçiçeği yağı ithalatına bağımlı ülkeler için önemli bir risk faktörü oluşturmaktadır. Türkiye, ayçiçeği yağı ihtiyacının büyük bir kısmını Ukrayna ve Rusya'dan karşılamakta olup, savaş nedeniyle bu tedarik zincirinde ciddi aksaklıklar yaşanmıştır. Bu çalışma, Rusya-Ukrayna savaşının Türkiye'deki ayçiçeği üretimi, ithalat bağımlılığı ve sektördeki kırılganlıklar üzerindeki etkilerini değerlendirmeyi amaçlamaktadır. Bu kapsamda, savaş öncesi ve savaş sonrası ithalat verileri, fiyat dalgalanmaları ve Türkiye'nin yerli üretim kapasitesindeki değişimler analiz edilmiş, sektördeki dışa bağımlılığın azaltılmasına yönelik politika önerileri tartışılmıştır. Bulgular, savaş nedeniyle Türkiye'de ayçiçeği yağı arzında ciddi bir dalgalanma yaşandığını, fiyatların arttığını ve yerli üretimin yetersiz kaldığını göstermektedir. Sonuç olarak, ayçiçeği yağı ithalatındaki dışa bağımlılığın azaltılması için yerli üretimin desteklenmesi, tedarik çeşitliliğini artıracak stratejiler geliştirilmesi ve tarım politikalarında uzun vadeli planlamalar yapılması önerilmektedir.

Anahtar Kelimeler: *Ayçiçeği Üretimi, Dışa Bağımlılık, Rusya-Ukrayna Savaşı, Tarım Politikaları, Gıda Güvenliği*

Giriş

Gıda güvenliği, 'tüm insanların her zaman, aktif ve sağlıklı bir yaşam için beslenme ihtiyaçlarını ve gıda tercihlerini karşılamak üzere yeterli, güvenli ve besleyici gıdaya fiziksel ve ekonomik erişime sahip olması' durumu olarak tanımlanmaktadır (FAO,1996). Birleşmiş Milletler Gıda ve Tarım Örgütü (FAO) tarafından ana hatları çizilen gıda güvenliğinin dört ana bileşeni bulunmaktadır. Bunlar, bulunabilirlik, erişim, kullanım ve istikrardır (Ericksen, 2008). Dört ana bileşen temel olarak kabul edilirken, eylem ve sürdürülebilirlik gibi belirli niteliklerden yoksundurlar. Bunlar, Sürdürülebilir Kalkınma Hedeflerine ulaşmak için gıda sistemlerinde gerekli değişiklikleri yapmak için kritik olarak kabul edilir (HLPE, 2020). Yapılan çalışmalar, silahlı çatışmaların ve savaşların küresel gıda güvensizliğinin en önemli itici güçlerini temsil ettiğini göstermektedir (FAO, 2017).

Ukrayna ve Rusya, küresel gıda tedarik zincirinde kritik bir konuma sahip olup, dünya buğday ihracatının yaklaşık %30'unu ve ayçiçeği yağı ile mısır gibi diğer stratejik tarım ürünlerinin önemli bir kısmını karşılamaktadır (Jagtap et al., 2022; Skydan et al., 2023; Chen et al., 2024). Savaş öncesinde Ukrayna'nın, dünya tahıl pazarına önemli miktarda ihracat gerçekleştirmesi beklenirken, askeri operasyonlar ve Karadeniz limanlarına uygulanan abluka nedeniyle bu faaliyetler ciddi şekilde sekteye uğramıştır (Liefert, 2023; Chepeliev et al., 2023). Ukrayna'nın

tarımsal üretiminde meydana gelen bu aksamalar derin bir nitelik taşımakta; mevcut raporlar, tarımsal üretimde önemli düşüşler yaşandığını ve bu durumun bölgede onlarca yıllık üretkenlik kazanımlarını tersine çevirebileceğini ortaya koymaktadır (Chen et al., 2024; Deininger et al., 2023).

Ukrayna'nın tarımsal ihracatına erişimin kısıtlanması, özellikle ithalata bağımlı ülkeler ve savunmasız nüfuslar üzerinde olmak üzere, küresel emtia fiyatlarının artmasına ve gıda güvensizliğinin derinleşmesine yol açmıştır (Deng et al., 2022; Benton et al., 2022). Küresel piyasalardaki yüksek derecedeki karşılıklı bağımlılık, çatışmanın etkilerinin Ukrayna ve Rusya sınırlarının ötesine yayılarak çok daha geniş bir coğrafyada ekonomik ve sosyal sonuçlar doğurmasına neden olmuştur.

Bu bağlamda, Rusya-Ukrayna Savaşı, özellikle ayçiçeği yağı ve türev ürünlerin önemli bir tedarikçisi olan Ukrayna'dan yapılan tarımsal ihracatın kesintiye uğramasıyla Türkiye'nin ithalat dinamiklerini doğrudan etkilemiştir. Ukrayna'nın, ayçiçeği yağı ihracatında önde gelen ülkelerden biri olması nedeniyle, savaşın üretim ve ihracat kapasitesinde yarattığı aksamalar, Türkiye'yi bu emtiadaki arz kıtlıkları ve fiyat dalgalanmalarına karşı daha kırılgan bir konuma getirmiştir (Fedulova, 2022). Ayrıca çatışmanın neden olduğu lojistik aksaklıklar ve ticaret yollarındaki belirsizlikler, Türkiye'nin gıda işleme sanayisi için kritik öneme sahip olan ayçiçeği ürünlerinin düzenli teminini riske atmıştır (Sezgin, 2022).

Bununla birlikte, savaş süreci Türkiye'yi, Ukrayna tarımsal ürünlerine olan ithalat bağımlılığı nedeniyle daha geniş ölçekli risklere de açık hale getirmiştir. Türkiye, önemli miktarda ayçiçeği ürününü Ukrayna'dan ithal etmektedir. Ancak, Rusya ve Ukrayna döviz piyasalarında yaptırımlar ve ticaret kesintileri sebebiyle yaşanan aksaklıklar, Türkiye'nin bu ürünlerde istikrarlı fiyat ve tedarik hacmi sağlamasını giderek güçleştirmiştir (Sezgin, 2022). Çatışmanın tetiklediği küresel gıda fiyatlarındaki artışlar ve tedarik zincirlerindeki kırılmalar, hem üreticiler hem de tüketiciler için maliyetlerin yükselmesine neden olmuştur. Bu gelişmeler, Türk tüccarları ve politika yapıcılarını, ayçiçeği ithalatındaki oynaklıkla ilişkili orta vadeli ekonomik etkileri azaltmak amacıyla ticaret stratejilerini yeniden değerlendirmeye ve tedarik kaynaklarını çeşitlendirmeye yöneltmiştir.

Türkiye'nin ayçiçeği ithalatına olan bağımlılığı, devam eden Rusya-Ukrayna çatışmasıyla birlikte daha görünür hale gelmiştir. Ukrayna'dan yapılan ihracattaki aksamalar, dalgalı uluslararası ticaret koşullarıyla birleşerek arz sıkıntılarına ve belirgin fiyat oynaklıklarına yol açmış; bu durum, Türk politika yapıcılarını acil stratejik adımlar atmaya zorlamıştır. Ortaya çıkan bu kırılganlığın giderilebilmesi, kısa vadede tedarik zincirinin istikrarını sağlamaya yönelik önlemler alınmasını, uzun vadede ise belirsizleşen küresel pazarlarda ulusal gıda güvenliğini güçlendirmek için ithalat kaynaklarının çeşitlendirilmesini gerekli kılmaktadır.

Bu çalışmanın amacı, Rusya-Ukrayna savaşının Türkiye'deki ayçiçeği üretimi, ithalat bağımlılığı ve sektördeki kırılganlıklar üzerindeki etkilerini değerlendirmeyi amaçlamaktadır. Bu kapsamda, savaş öncesi ve savaş sonrası ithalat verileri, fiyat dalgalanmaları ve Türkiye'nin yerli üretim kapasitesindeki değişimler analiz edilmiştir. Çalışma, ulusal gıda güvenliğini güçlendirmek amacıyla alternatif tedarik stratejilerinin geliştirilmesine yönelik politika önerileri sunmayı hedeflemektedir.

Materyal ve Yöntem

Bu çalışma, Rusya-Ukrayna Savaşı'nın Türkiye'deki ayçiçeği üretimi, ithalat bağımlılığı ve sektördeki kırılganlıklar üzerindeki etkilerini değerlendirmek amacıyla gerçekleştirilmiştir. Çalışmada, Türkiye'nin 2001-2024 yılları arasındaki ayçiçeği ithalat verileri, fiyat dalgalanmaları ve yerli üretim kapasitesindeki değişimler analiz edilmiştir. Veri kaynakları olarak Türkiye İstatistik Kurumu (TÜİK) ve FAO gibi ulusal ve uluslararası veri tabanlarından elde edilen istatistikler kullanılmıştır. İthalat verileri, ayçiçeği ithalatının yapıldığı ülkeler ve ithalat oranlarını içerirken, fiyat verileri yurt içi ayçiçeği fiyatlarındaki yıllık değişimleri kapsamaktadır. Yerli üretim kapasitesindeki değişimler ise yıllık üretim miktarları ve değişim oranları üzerinden analiz edilmiştir. Araştırmada kullanılan değişkenler ve sembolleri şu şekildedir. X1: UFE, X2: dolar/TL kuru, X3: ithalat miktarı (ton), X4: üretim (ton), X5: ihracat (ton), X6: ithalat oranı (%), X7: yerli üretim oranı (%), X8: yurt içi fiyat (TL, kg), X9: kırılganlık endeksi dir. Ayçiçeği ithalatını etkileyen faktörlere ilişkin normalizasyon değerleri hesaplanmış ve sektördeki kırılganlığın ölçülmesinde ise Min-Max Normalizasyonu ile Kırılganlık Endeksi hesaplanmıştır. Endeks değeri 1' e yaklaştıkça kırılganlığın arttığı, 0' a yaklaştıkça kırılganlığın azaldığı ifade edilebilir. Bu endeks, ithalatı etkileyen çeşitli ekonomik göstergelerin (ÜFE, döviz kuru, ithalat miktarı, üretim, ihracat, fiyat vb.) normalizasyonu ile elde edilmiş ve sektörün dış şoklara karşı ne kadar hassas olduğunu göstermek amacıyla kullanılmaktadır. Çalışma sonucunda elde edilen bulgular, Türkiye'nin ayçiçeği sektöründeki dışa bağımlılık ve kırılganlık durumunu ortaya koyarak, bu bağımlılığı azaltmaya yönelik politika önerileri geliştirilmesine katkı sağlamayı amaçlamaktadır

Araştırma Bulguları

Türkiye'nin ayçiçeği ithalatında en büyük pay Ukrayna, Bulgaristan, Romanya ve Moldova arasında paylaşılmıştır. 2010 sonrası Rusya önemli bir aktör olmuş; fakat siyasi gerilimler etkisiyle 2022 sonrası Ukrayna ve Romanya yeniden öne çıkmıştır. Avrupa ülkeleriyle yakınlık ve lojistik avantajları bu ülkeleri öncelikli hale

getirmiştir. 2022–2023'teki değişimler, savaş ve küresel gıda krizi gibi dışsal faktörlerin etkisini açıkça göstermektedir. Ukrayna, 2001'de %35,95 oranla ithalatta en büyük paya sahip ülke konumundaydı. 2010'ların ortasında payı düşse de 2022'de %68 ile yeniden zirve yapmıştır. Dikkat çeken dönem ise 2022 yılı olmuştur. 2022 yılında ithalatın %68'i Ukrayna'dan yapılmıştır. Bu artış, Rusya-Ukrayna Savaşı'na rağmen Türkiye' nin bölgedeki etkin konumundan kaynaklı oluşturulan Karadeniz Tahıl Koridoru anlaşmasının etkisiyle açıklanabilir. Ukrayna Türkiye'nin ayçiçeği ithalatında en istikrarlı ve baskın aktörlerden biri olmaya devam etmektedir. Bulgaristan Ayçiçeği ithalatında 2001–2010 arasında Türkiye'nin en büyük tedarikçisi olmuştur. 2005'te %80,29 ile tarihi bir zirve yapmıştır. 2015 sonrası payı ciddi oranda azalmış ve 2022'de ancak %3,58 oranından gerçekleşmiştir. Bu durum, AB üyeliği ve iç pazar değişimleriyle Türkiye pazarındaki rolünün zayıflamasıyla açıklanabilir. Her ne kadar 2023'te bir toparlanma görülse de Türkiye üzerinde ayçiçeği ihracatı bakımından eski gücünden uzak olarak değerlendirilebilir. Değişken bir grafik izledi. 2015'te %64,12 ile önemli bir zirve yaptı. Türkiye'nin ayçiçeği ithalatında Moldovya'nın durumu incelendiğinde, 2001–2023 arası en fazla dalgalanan ülkelerden biri olarak görülmektedir. 2023 yılına gelindiğinde Türkiye'nin ithalatındaki payı %4,39'a kadar gerilemiştir. Coğrafi yakınlık ve lojistik avantajına rağmen tedarik sürekliliği konusunda istikrarsız bir süreç izlediği ifade edilebilir. Romanya, Türkiye için Orta düzeyde bir tedarikçi olarak tanımlanabilir. 2006 ve 2014 yıllarında Türkiye ayçiçeği tedarik payının %27–30 seviyelerine ulaştığı görülmektedir. Uluslararası dengelerden kaynaklı olarak 2014'ten sonra Türkiye üzerindeki etkinliğini yavaş yavaş kaybetse de 2023'te tekrar %28,01'e çıkarak önemli bir tedarikçi rolü misyonunu üstlenmiştir. Romanya, Türkiye'ye coğrafi yakınlık ve AB üyesi olması nedeniyle güvenli ve artan tedarikçi etkinliğine sahip bir konumunda düşünülebilir. Rusya ise, 2012 ve 2020 yıllarında Türkiye'ye ayçiçeği ihracatı bakımından önemli sıçramalar yapmıştır. 2020'de %58,10'luk oranla zirve yapmış ancak 2021 sonrası payı ciddi şekilde düşmüştür (2021:%1,36 -2022:%0,01). Politik riskler ve savaş sonrası Türkiye ithalatını yeniden Ukrayna ve Romanya'ya kaydırmıştır.

Tablo 2 incelendiğinde ÜFE, genel ekonomik eğilimleri ve tarım sektöründeki maliyetleri yansıttığı düşünüldüğünde, 2001'de 15,18 olan ÜFE, 2024'te 1.350,54'e yükselmiştir. Yaklaşık 90 katlık artış, enflasyonist baskıların yoğunluğunu ve tarımsal girdi fiyatlarındaki ciddi yükselişi göstermektedir. Özellikle 2021–2022 arasında ÜFE'deki artış %141,4'tür. Bu, küresel gıda ve enerji krizlerinin etkisinden kaynaklı artışları işaret etmektedir. Çünkü hem döviz kuru hem ithalat hem de ihracat maliyetlerini doğrudan etkiler. 2001'de 1,23 TL olan dolar kuru, 2024'te 32,79 TL'ye yükselmiştir. Bu süreçte TL'nin ciddi şekilde değer kaybettiği anlaşılmaktadır. 2021–2022 döneminde %86,3'lük artış, ithalat maliyetlerini artırıcı bir etkiye sahiptir. Ayçiçeği ithalatı değerlendirildiğinde, 2001 yılında 552 bin ton olan ithalat, 2023 yılında 5,8 milyon tonla zirve yapmış, 2024'te 4,59 milyon tona gerilemiştir. Bu durum, yerli üretimin yetersizliğini ve ayçiçeğinde dışa bağımlılığın artışını gösterir. 2002'de ithalat %49 artarken, 2012'de bir önceki yıla göre %45,6 oranında artmıştır.

Tablo 1. Türkiye'nin 2001-2023 yılları arası Ayçiçeği İthalatı Yaptığı Ülkeler ve Oranları

Yıl	Arjantin	Bulgaristan	Çin	Fransa	Moldova	Romanya	Rusya	Sırbistan	Ukrayna
2001	0,73	33,66	0,17	0,01	4,20	25,27	0,00	0,00	35,95
2002	1,65	48,56	0,00	9,52	3,85	17,65	0,00	0,00	18,77
2003	0,21	42,26	0,00	0,03	0,48	9,81	0,00	0,00	47,21
2004	0,10	54,85	0,01	0,01	5,48	3,49	0,00	0,00	36,06
2005	0,29	80,29	0,06	0,01	4,04	6,50	8,52	0,00	0,28
2006	0,15	44,45	0,14	0,01	9,18	27,09	16,81	0,00	2,17
2007	0,32	41,81	0,09	0,01	8,50	38,99	0,01	0,00	10,28
2008	0,07	56,08	0,85	0,01	6,84	30,42	0,99	0,00	4,74
2009	0,30	47,92	0,39	0,01	12,62	11,10	0,88	0,00	26,78
2010	0,14	40,63	0,38	0,05	8,61	12,16	0,00	0,00	38,03
2011	0,08	28,33	0,19	0,00	22,02	15,23	5,12	0,00	29,04
2012	0,06	19,77	0,17	0,01	13,52	10,49	32,28	0,00	23,71
2013	0,14	30,64	0,53	0,01	28,78	27,03	4,38	0,00	8,49
2014	0,24	18,53	0,89	0,01	36,89	30,72	9,18	0,16	3,38
2015	0,29	17,57	1,94	0,02	64,12	10,13	5,34	0,00	0,60
2016	8,25	13,73	1,15	0,06	45,84	14,86	13,06	1,84	1,20
2017	0,18	14,43	3,30	0,03	35,01	6,27	35,83	0,00	4,94
2018	0,11	14,28	11,69	0,04	37,54	35,10	0,41	0,03	0,81
2019	2,64	6,97	7,65	0,01	32,72	21,67	24,51	1,52	2,32
2020	4,74	7,78	8,89	2,12	9,68	3,96	58,10	1,07	3,66
2021	5,50	24,58	11,59	2,05	23,95	21,85	1,36	0,95	8,17
2022	0,35	3,58	2,19	0,02	14,10	11,76	0,01	0,00	68,00
2023	0,52	10,01	4,10	0,02	4,39	28,01	2,86	0,10	50,00
Toplam	1,35	25,21	3,45	0,38	19,93	17,87	13,39	0,35	18,07

Tablo 2. Türkiye'nin 2001-2024 yılları arası Ayçiçeği Üretim ve Dış Ticareti Üzerinde Etkili Olan Bazı Parametrelere İlişkin Yıllık Değişim Oranları

Yıl	ÜFE*	$Kuru	İthalat	Üretim	Stok	İhracat	Yurtiçi Arz	İthalat Oranı	Yerli Üretim Oranı	Fiyat
2001	-	-	-	-	-	-	-	-	-	-
2002	43,68	22,76	49,13	-18,75	-856,3	-48,04	6,28	51,44	-34,78	59,26
2003	47,82	-1,32	-60,2	30,77	-106,07	65,7	-18,44	-54,74	85,94	81,4
2004	32,1	-4,7	188,05	-5,88	781,41	0,31	61,55	88,5	-33,82	10,26
2005	10,47	-5,63	1,78	12,5	-152,56	-6,9	1,59	1	-1,09	3,49
2006	6,59	6,72	76,43	8,33	32,09	97,17	38,65	22,76	-25,3	24,72
2007	18,13	-9,09	-46,19	14,67	-3,53	-62,75	-19,15	-28,89	52,77	3,6
2008	10,99	-0,77	61,72	-23,58	114,71	77,42	8,45	43,76	-37,21	26,96
2009	0,15	20,16	13,58	16,1	-235,9	102,2	17,52	-9,37	18,24	-3,42
2010	14,52	-3,23	-24,62	6,57	-128,64	-45,22	-13,76	-7,57	11,29	8,51
2011	2,68	11,33	46,56	24,87	-515,35	122,34	37,26	0,54	-0,67	9,8
2012	1,61	7,19	45,55	1,14	-91,11	71,48	12,53	19,77	-24,8	7,14
2013	1,44	6,15	-6,97	2,62	2453,05	6,25	4,2	-11,1	22,18	-12,78
2014	18,41	15,26	11,72	11,17	-120,82	97,59	-26,73	11,24	-16,34	85,99
2015	6,54	24,2	-0,06	7,54	-427,93	7,74	11,88	-9,23	17,83	-33,56
2016	4,1	11,03	-15,61	2,61	-65,19	-6,87	-15,37	-4,33	6,45	8,76
2017	3,99	20,86	21,26	-0,59	-150,45	7,74	9,75	11,39	-15,24	13,74
2018	18	31,78	-24,34	17,58	181,64	-39,09	11,57	-15,28	26,87	13,75
2019	22,38	17,88	26,8	-0,77	-223,62	34,63	14,84	5	-5,87	12,82
2020	15,22	23,63	20,16	7,73	-114,52	19,78	6,66	8,2	-10,74	53,57
2021	25	26,82	-5,02	-1,57	461,79	4,38	-11,14	0,55	-0,88	36,15
2022	141,46	86,28	40,55	16,84	-113,59	36,52	33,27	4,44	-7,15	92,24
2023	73,19	43,36	32,3	5,59	36,26	23,07	22,74	7,68	-13,92	8,97
2024	42,47	38,12	-21,22	-13,8	206,63	7,9	-36,24	-3,5	7,94	48,26
Ortalama	23,37	16,20	17,97	5,07	40,08	23,89	6,58	5,51	0,90	23,32

*ÜFE (2015=100 endeks değerinden hareketle değişim oranları hesaplanmıştır). Kaynak: TUIK, 2025 ve yazar hesaplamaları.

2020 sonrası ithalat hızla artmış, bu da yerli üretimle arzın karşılanamadığını ifade etmektedir. Tablo 2'den ayçiçeği üretimi incelendiğinde 2002 yılında %18,75'lik ciddi bir düşüş dikkat çekmektedir. Bu düşüş Türkiye' deki 1999 ve 2001 krizlerinin etkisiyle ortaya çıkan gerilimden kaynaklı olabileceği gibi iklimsel faktörler ve dönemin koşullarında kamu destekleme politikalarındaki yönlendirici etkinin zayıflığından ortaya çıktığı düşünülebilir. 2003 yılında görülen %30,77'lik artış ise, üreticinin yeniden üretime yönelmesini ve toparlanmayı göstermektedir. 2008 yılında %23,5 oranında bir azalış görülmekte olup ilgili yıldaki küresel krizin etkileri ve kuraklık kaynaklı bir azalışın sonucu olarak değerlendirilebilir. 2011–2015 yılları arasında üretim istikrarlı bir şekilde artmış, bu dönem devlet desteklerinin artması ve tarımsal verimliliğin yükselmesiyle ilişkilendirilebilir. 2022 ve 2023'teki artışlar, ithalat oranlarının yükselmesine rağmen yerli üretimin artırıldığını göstermektedir. 2024'teki %13,8 oranındaki düşüş, maliyet artışları, iklimsel sorunlar veya çiftçinin ayçiçeğinden uzaklaşması gibi nedenlerle açıklanabilir. Stok seviyeleri incelendiğinde, dalgalı bir seyir izlemektedir. Negatif stok değişimleri (örneğin 2002, 2005, 2006) arz-talep dengesizliğini yansıtırken, yüksek stok artışları (örneğin 2013, 2015) ithalat fazlası veya talep düşüşü anlamına gelmektedir. 2013'te stoklar %2453 artmış, bu da beklenmedik dış ticaret hareketleriyle açıklanabilir. İhracat oranları genel olarak düşük seviyededir. 2001'de 196 bin ton olan ihracat, 2024'te 3,67 milyon tona çıkmıştır. Ancak bu rakam, ithalatın oldukça gerisindedir. Özellikle 2010–2012 arası ihracatta %270'lik bir artış görülmektedir. Ancak bu artışlar da ithalatı dengeleyecek düzeyde değildir. Arz miktarı üretim + ithalat – ihracat ± stoklarla belirlenir. Süreç içinde artış göstermekle birlikte 2001'de 1,17 milyon ton olan yurtiçi arz, 2023'te 5 milyon tonu aşmıştır. 2004 yılında arzda %61'lik bir sıçrama görülmüştür. İthalat oranı değerlendirildiğinde bu oran toplam arz içindeki ithalat payını gösterir. 2001'de %40,34 olan oran, 2023'te %69,39'a ulaşmıştır. 2024'te %66,96'ya gerilese de hâlâ çok yüksektir. Bu artış, yerli üretimin arzı karşılamada yetersiz kaldığını ve dışa bağımlılığın arttığını göstermektedir. Yerli üretim oranı ise toplam arz içindeki yerli üretimin payıdır. 2001'de %59,66 olan oran, 2023'te %30,61'e kadar düşmüştür. 2024'te %33,04'e küçük bir toparlanma yaşanmıştır. Bu azalma, yerli üretimin görece gerilediğini ve arz içinde ithalatın payının giderek arttığını kanıtlar niteliktedir. Ayçiçeğinde yurt içi fiyat seyri incelendiğinde, 2001'de 0,27 TL olan fiyat, 2024'te 20,00 TL'ye ulaşmıştır. Bu 74 katlık artış hem maliyet artışları hem de arz-talep dengesizliklerinden kaynaklanmaktadır. En çarpıcı artış 2021–2022 arasında yaşanmış olup %92'lik bir fiyat sıçraması görülmektedir. 2023'te fiyat %9 oranında artarken, 2024'te %48,3'lük dev bir artış kaydedilmiştir. Bu, ithalatın ilgili yılda azalması ve maliyet artışlarından kaynaklı olabileceği düşünülen üretimin azalmasının sonucu olarak değerlendirilebilir.

Tablo 3. Türkiye'nin 2001-2024 yılları arası Ayçiçeği İthalatını Etkileyen Faktörlerin Min-Max Normalizasyonu ile Hesaplanmış Kırılganlık Endeksleri

Yıl	X1 ufe	X2 dolarkuru	X3 ithalat/ton	X4 üretim	X5 ihracat	X6 ithoran	X7 yerlioran	X8 fiyat	X9 kırılganlık	X9'daki değişim
2001	0,00	0,00	0,04	0,08	0,03	0,30	0,30	0,00	0,09	0,00
2002	0,00	0,01	0,09	0,00	0,00	0,80	0,80	0,01	0,21	127,29
2003	0,01	0,01	0,00	0,11	0,02	0,00	0,00	0,03	0,02	-90,01
2004	0,02	0,01	0,11	0,08	0,02	0,59	0,59	0,03	0,18	740,34
2005	0,02	0,00	0,12	0,13	0,02	0,60	0,60	0,03	0,19	5,52
2006	0,03	0,01	0,25	0,17	0,06	0,89	0,89	0,04	0,29	53,08
2007	0,03	0,00	0,11	0,25	0,00	0,44	0,44	0,04	0,16	-43,51
2008	0,04	0,00	0,21	0,11	0,03	0,92	0,92	0,06	0,29	74,12
2009	0,04	0,01	0,24	0,18	0,09	0,77	0,77	0,06	0,27	-5,40
2010	0,05	0,01	0,17	0,21	0,04	0,66	0,66	0,06	0,23	-13,83
2011	0,05	0,01	0,28	0,35	0,11	0,67	0,67	0,07	0,28	18,90
2012	0,05	0,02	0,43	0,36	0,22	0,93	0,93	0,08	0,38	36,15
2013	0,05	0,02	0,40	0,38	0,23	0,76	0,76	0,07	0,33	-12,01
2014	0,06	0,03	0,45	0,46	0,48	0,92	0,92	0,13	0,43	29,90
2015	0,06	0,05	0,45	0,52	0,52	0,77	0,77	0,08	0,40	-6,36
2016	0,07	0,06	0,37	0,54	0,48	0,71	0,71	0,09	0,38	-6,12
2017	0,07	0,08	0,46	0,54	0,52	0,87	0,87	0,11	0,44	15,69
2018	0,08	0,11	0,33	0,69	0,31	0,63	0,63	0,12	0,37	-16,72
2019	0,11	0,14	0,44	0,68	0,43	0,70	0,70	0,14	0,42	14,04
2020	0,12	0,18	0,54	0,76	0,51	0,81	0,81	0,23	0,50	19,11
2021	0,16	0,24	0,51	0,75	0,54	0,82	0,82	0,31	0,52	4,35
2022	0,40	0,49	0,74	0,93	0,75	0,88	0,88	0,61	0,71	37,12
2023	0,70	0,71	1,00	1,00	0,92	1,00	1,00	0,67	0,88	23,41
2024	1,00	1,00	0,78	0,81	1,00	0,94	0,94	1,00	0,93	6,66

İthalat üzerinde etkili olan faktörlere ilişkin kırılganlık endeksleri yıllar itibariyle incelendiğinde, 2001–2010 döneminde, kırılganlık endeksi 0,09 ile 0,23 arasında değişmiştir. Türkiye'nin yerli ekonomik anlamda istikrarlı yapısı, düşük döviz ve girdi fiyatları sayesinde arz güvenliğinin bu dönemde yüksek olduğu ifade edilebilir. 2011–2019 döneminde, endeks değerleri 0,28 ile 0,42 arasında seyretmiş, kırılganlık orta düzeye ulaşmıştır. Bu dönemde ithalat oranı artmış, döviz kuru dalgalanmış, yerli üretimin artış hızı ithalat oranı artış hızının gerisinde kalmaya başlamıştır. 2020–2021 döneminde, pandemi sonrası yaşanan tedarik zincirindeki kopmalar, ülkelerin korumacı yönlü üretim ve Pazar davranışları fiyat artışları ve girdi maliyetlerindeki yükseliş olarak boyutlanmış ve kırılganlık endeksi 0,50 seviyelerine çıkmıştır. 2021 yılında endeks 0,71 olarak hesaplanmıştır. 2022–2024 döneminde ise, Rusya-Ukrayna savaşının etkisiyle kırılganlık zirve yapmıştır. 2022'de endeks 0,88, 2023'te 0,93 ve 2024'te 1,00 olarak ölçülmüştür. Bu dönemde hem ithalat oranı hem de fiyatlar maksimum seviyeye ulaşmış, yerli üretimin payı ise minimum olarak görülmüştür. Elde edilen sonuçlara göre, Türkiye'nin ayçiçeği arzındaki dışa bağımlılığı ve yapısal kırılganlığı 2020 sonrası dönemde ciddi ölçüde artmıştır. Özellikle 2022 sonrası yaşanan jeopolitik gelişmeler ve döviz bazlı maliyet artışları bu kırılganlığı daha da derinleştirmiştir.

Sonuç ve Öneriler

2001–2024 dönemi incelendiğinde, Türkiye'nin ayçiçeği sektöründe üretimin artmasına rağmen ithalatın daha hızlı bir ivmeyle yükseldiği, dolayısıyla yerli üretimin toplam arz içerisindeki payının gerilediği görülmektedir. Bu süreçte döviz kuru ve üretici fiyat endeksindeki (ÜFE) hızlı artışlar, üretim maliyetlerini ve nihai ürün fiyatlarını önemli ölçüde yukarı çekmiştir. İthalat oranının %70 seviyelerine ulaşması, tarımsal dışa bağımlılığın belirgin şekilde arttığını göstermektedir. Aynı dönemde fiyatlardaki dalgalanmalar, hem üreticilerin üretim kararlarını hem de tüketicilerin alım gücünü ciddi şekilde etkilemiştir. Türkiye'nin ayçiçeği ithalatında başlıca tedarikçiler arasında Bulgaristan ve Ukrayna öne çıkmaktadır; Bulgaristan 2005 yılında %80,29 ile tarihsel olarak en yüksek ithalat payına ulaşmıştır. Ukrayna ise özellikle son yıllarda önemli bir tedarikçi konumuna gelmiştir. 2011–2019 döneminde ithalatın ülkesel çeşitliliği artmış; Romanya, Moldova ve Rusya gibi ülkelerin payı belirgin şekilde yükselmiştir. Bu durum, Türkiye'nin ithalat politikasında kaynak çeşitlendirmeye yönelik bir strateji izlediğine işaret etmektedir. 2020–2023 döneminde ise, jeopolitik gelişmeler ithalat dinamiklerini yeniden şekillendirmiştir. 2020 yılında Rusya %58'lik payla en yüksek seviyeye ulaşırken, 2022 yılında Ukrayna %68'lik rekor bir oranla Türkiye'nin en büyük tedarikçisi olmuştur. Gelinen noktada, Türkiye'nin ayçiçeği ithalatında aşırı bağımlılığı (örneğin Ukrayna'ya %68 oranında bağımlılık), bölgesel krizler (Rusya-Ukrayna Savaşı) ve

lojistik/tedarik zinciri aksamaları gibi önemli riskler barındırmaktadır. Hassan ve Bilali (2022) yaptıkları çalışmada, Türkiye'nin, Rusya-Ukrayna savaşı sırasında tedarik zincirinde zorluklar yaşadığını belirtmiştir. Ayrıca Han vd. (2023), savaşın küresel gıda fiyat enflasyonunu artırdığını belirtmiştir. Bu durum, özellikle ithalata bağımlı ülkeler için gıda arz güvenliğini ve fiyat istikrarını daha kırılgan hale getirmiştir. Türkiye ise, yakın coğrafyadaki alternatif tedarikçilere erişim imkânı, bölgesel diplomatik ilişkilerdeki gücü ve yerli üretim kapasitesini artırma potansiyeli gibi önemli fırsat alanlarına sahiptir.

Bu veriler ışığında, Türkiye'nin tarımsal sürdürülebilirliği ve gıda güvenliği açısından yerli üretimi artırıcı politikalar geliştirmesi, ithalata olan bağımlılığı azaltacak stratejiler uygulaması, kriz dönemleri için kamu ve özel rezerv/muhafaza/depo sistemlerinin aktif olması ve jeopolitik olarak riskleri öngörebilecek şekilde aksiyoner olması önemli görülmektedir.

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Evaluation of *Bacillus* Strains for Protease Production

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Abstract

Proteases have diverse industrial applications, particularly in laundry detergents and the leather industry, as well as in the food, textile, and pharmaceutical sectors. While plant- and animal-derived proteases are traditionally used, their production is limited by environmental and agricultural constraints. Microorganisms, especially *Bacillus* species and lactic acid bacteria, have emerged as key sources due to their high yield and ease of biotechnological manipulation, accounting for nearly 60% of global commercial enzyme sales. This study aimed to evaluate protease production in *Bacillus* isolates obtained from food and soil samples. Eight isolates were screened on milk powder-containing agar, and six demonstrated significant protease activity. The isolates ZGT9, EBTA7, and ZBP10 showed the largest clear zones (20.0, 18.8, and 18.5 mm, respectively) and were selected for further investigation. Crude enzymes were obtained from 48-hour nutrient broth cultures, and protease activity was assessed using 1% casein solution at pH 8 and 60°C for 15 minutes. Protein concentrations were determined using Bradford assay, with BSA as the standard. Total protein content ranged from 112.6 to 182.6 µg BSA eq./mL, while protease activity varied between 360.8 and 2530.8 U/mL. Specific activities ranged from 3221 to 13,862 U/mg. The isolate with the highest activity (EBTA7) was further analyzed to determine its optimal operating conditions. Enzyme activity was evaluated at various pH (7–11) and temperature (50–80°C) values. The enzyme showed maximal activity at 60°C and pH 9, with high relative activity at 50°C (76%) but a sharp decline above 60°C (35% at 70°C, 29% at 80°C). These results indicate that the enzyme is moderately thermophilic and functions best under alkaline conditions. Biochemical characterization and 16S rDNA gene sequence analysis confirmed that the strain belongs to the *Bacillus* genus.

Key Words: *Microbial proteases, Bacillus, protease activity*

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Tracking *Salmonella* in Sesame Foods: Genomic Diversity and Resistance Patterns

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Abstract

Sesame-based products such as tahini and halva have gained international popularity due to their nutritional benefits and cultural significance. However, their association with recent *Salmonella* outbreaks and recalls has raised global concerns regarding their microbiological safety. Despite low water activity traditionally limiting microbial growth, these products have demonstrated the ability to harbor *Salmonella* for extended periods, leading to recalls and international trade disruptions.

This study aimed to investigate the molecular epidemiology of *Salmonella* strains isolated from sesame, tahini, and halva. Genome assemblies were obtained from the NCBI database and filtered based on product metadata. Quality control assessments were performed using CheckM and QUAST to ensure high-quality genomes. Serotyping and core genome multilocus sequence typing (cgMLST) were conducted using SISTR, while resistance genes, virulence factors, and plasmid content were identified using Abricate and Bakcharak. Pangenome analysis was performed with Roary, and phylogenetic relationships were inferred using IQ-TREE with 1,000 bootstrap replicates.

The analysis revealed notable genomic diversity among the *Salmonella* isolates, with multiple serovars and cgMLST types identified across the three commodity groups. Several isolates carried clinically relevant antimicrobial resistance genes and virulence factors, including those linked to enhanced environmental persistence. Phylogenomic analysis showed both commodity-specific clustering and instances of inter-commodity genetic similarity, indicating potential shared contamination sources or cross-contamination events.

These findings underscore the importance of genomic surveillance in tracking the emergence and dissemination of foodborne pathogens in low-moisture foods. By applying molecular epidemiology approaches, this study contributes to the understanding of *Salmonella* diversity, resistance, and distribution in sesame-based products and highlights the need for proactive food safety strategies in international supply chains.

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Impact of Varying *Moringa oleifera* Leaf Diets on Productive Performance and Reproductive Characteristics of Nubian Goats

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Abstract

This study investigated the effects of *Moringa oleifera* (*M. oleifera*) supplementation on fetal growth in Nubian goats within the Butana region, utilizing real-time ultrasonography. The research aimed to explore the relationship between gestational age and key fetal measurements, including crown rump length (CRL), biparietal diameter (BPD), and femur length (FL). A total of 200 Nubian female goats, aged 24.00 ± 0.75 months and weighing 46.42 ± 2.96 kg, were randomly selected from a large herd and assigned to four groups (n=50 each) based on their dietary supplementation of *M. oleifera*: Group A (0%, control), Group B (20%), Group C (40%), and Group D (60%). Pregnancy was confirmed through management practices and transabdominal ultrasound. Fetal measurements were taken at three distinct stages of gestation to assess CRL, BPD, and FL. Results indicated significant differences in CRL measurements at day 45 of gestation ($p < 0.05$), with Group C exhibiting the highest mean measurement and Group D the lowest. At day 80, significant differences were observed in FL and BPD measurements among the groups ($p < 0.05$). The study also found significant correlations between CRL, BPD, and FL with gestational age ($p < 0.05$), with FL demonstrating the strongest positive correlation (R = 0.957), followed by BPD (R = 0.614) and CRL (R = 0.501). In conclusion, *M. oleifera* supplementation significantly influenced fetal growth parameters, particularly CRL, FL, and BPD. These findings suggest that dietary supplementation of *M. oleifera* may enhance fetal development in Nubian goats, highlighting its potential benefits in goat husbandry.

Key Words: *Moringa oleifera,* Nubian goats, Fetal growth, Reproductive characteristics, Dietary supplementation.

Introduction

Goats significantly contribute to the livelihoods of many countries and communities in Africa, offering vital resources such as milk and meat, especially to those in rural areas (Alfadul et al., 2024; Saleh et al., 2021; Saleh et al., 2023). This agricultural relevance becomes even more pronounced with the Nubian goat, one of the world's oldest and most renowned dairy breeds. Native to the Nubian desert region extending to parts of northern Sudan and Southern Egypt, Nubian goats are lauded for their adaptability to harsh climates and their dual-purpose utility in milk and meat production (Brewer et al., 2024; Trimingham, 1960).

Despite advancements in agricultural practices, goats remain vital to subsistence and smallholder systems, as evidenced by ongoing efforts to enhance the productivity of the Nubian breed through crossbreeding with other high-yielding varieties like the Saanen (Agossou and Koluman, 2017; Strahsburger and Scopinich-Cisternas, 2021). This breed is pivotal to Sudan's goat population, representing nearly half of the total (Ali, 2010; Ibrahim et al., 2022). Nonetheless, fully optimizing their production potential requires a profound understanding of their nutritional and reproductive needs (Saleh and Hassanine, 2019).

The reproductive and productive potential of goats can be significantly improved with adequate supplemental feeding, especially in arid areas where feed resources become scarce and costly (Ali, 2010; Mellado et al., 2022; Urrutia-Morales et al., 2012; Zewdie and Welday, 2015). This reality has driven a search for alternative, cost-effective feed solutions enriched in protein and minerals to enhance livestock productivity (Boudalia et al., 2024; Makkar et al., 2022; Misra and Kumawat, 2021; Salem and Smith, 2008; Singh and Chauhan, 2017). Among the alternative feed sources, the leaves of *Moringa oleifera* (*M. oleifera*) have emerged as a promising candidate.

Known for its high protein content and essential nutrients, *M. oleifera* potential as a livestock feed supplement is gradually gaining recognition, although its utility remains underexplored (Dantas et al., 2024; Kekana et al., 2021; Matic et al., 2018; Moustafa and Assem, 2024; Patir, 2022; Parkunan et al., 2024).

M. *oleifera*, often cultivated in various parts of Africa, is renowned for its nutritional value. It is high in crude protein, vitamins, and essential minerals, which suggests it could fulfill the dietary needs of livestock, improve their nutritional status, and subsequently, enhance their productive and reproductive performance (Divya et al., 2024; Farrag, 2024; Mashamaite et al., 2024b; Worku et al., 2024).

Moreover, the benefits of *M. oleifera* extend beyond nutritional enhancements (Divya et al., 2024; Mohamed Husien et al., 2022). Its incorporation into the diets of ruminants has shown promising results in improving reproductive parameters due to the presence of bioactive compounds such as flavonoids and antioxidants, which can positively influence reproductive efficiency and outcomes (Divya et al., 2024; Xu et al., 2024). The antioxidants present in *M. oleifera* may help enhance productive and reproductive health by mitigating oxidative stress, which is crucial for maintaining high fertility rates and improving the overall breeding success of goats (El Bilali et al., 2024; Shea, 2024). By exploring alternative feed resources like *M. oleifera*, there is a dual benefit of improving livestock performance and ensuring sustainability in farming practices, which is especially pertinent in regions that face environmental and economic challenges (Delfín-Portela et al., 2024; El Bilali et al., 2024; Kumssa et al., 2017; Mashamaite et al., 2024a; Rahman et al., 2024).

The integration of *M. oleifera* as a sustainable feed resource aligns with global efforts to enhance animal nutrition while reducing costs (Akintan et al., 2024; Husien et al., 2024; Lungu et al., 2024; Makkar, 2016). The tree's leaves, pods, and seeds have been noted for their high crude protein content and an array of essential vitamins and minerals that contribute to improved animal health and productivity (Divya et al., 2024; Farrag, 2024; Mashamaite et al., 2024b; Worku et al., 2024). *M. oleifera* adaptability to semi-arid climates and its resistance to drought make it a viable option for regions such as the Sudanese Butana area, where conventional feed resources are often scarce or prohibitively expensive. This adaptability, coupled with its high nutritional profile, positions *M. oleifera* as a potential game-changer in livestock feeding strategies, allowing for improved body condition and milk production without the high costs associated with traditional feed (Kholif et al., 2015).

This study seeks to examine the impacts of feeding varying levels of *M. oleifera* leaves on the reproductive and productive traits of Nubian goats in Sudan, Butana area. Specifically, it aims to assess the influence of *M. oleifera* supplementation on; **a**) blood serum parameters such as total protein and mineral composition, **b**) evaluate the reproductive performance indicators including oestrus response and pregnancy rates, and **c**) determine the effects on body weight, milk yield and composition. Through this research, the study provided further insights into how *M. oleifera* supplementation can be practically applied to optimize the productivity of Nubian goats, enhancing both economic and nutritional outcomes for the farming communities.

Materials and Methods

Study Area

This research was carried out at the farm of the College of Agricultural Sciences, University of Gezira, Wad Medani, Gezira State, Sudan (GPS: 14o 23' 9.51" N, 33o 31' 46.85" E), which is situated in the eastern region of Gezira State. The area's climate features a rainy season from July to October and a dry season from February to May, with average daily temperatures ranging from 37°C to 39°C. The study was conducted over the period from April 2023 to April 2024.

Experimental design

A total of 200 goats were randomly selected from a flock of 500. Non-pregnancy was confirmed using ultrasonography. The goats were approximately 24.00±0.75 months old and 46.42±2.96 kg. Each goat underwent a comprehensive physical and vaginal examination and was determined to be in good health. The goats were housed in separate pens, ear-tagged, and allowed a 10-day acclimation period. They were given oral deworming treatments with 10 ml (10 mg/ml) of Albendazole in two doses over fifteen days and subcutaneous injections of 1 ml Ivomec (Ivermectin 10 mg/ml), as well as Cypermethrine (Cypermethrine 10% EC) washes. Additionally, they received intramuscular injections of Oxytetracycline 20%, 3 ml per doe/48h. The animals were then randomly divided into four groups, each containing five goats, housed separately from males.

Feeding

During the study, goats were provided daily with 500 g of a balanced concentrate diet consisting of 30% sorghum, 50% wheat bran, and 20% molasses. Mineral salt and water were available *ad libitum*. The goats were organized into four groups based on the proportion of *M. oleifera* leaves in their roughage: group A (control) received 100% groundnut hulls with no *M. oleifera*, group B received 20% *M. oleifera* and 80% groundnut hulls, group C received 40% *M. oleifera* and 60% groundnut hulls and group D received 60% *M. oleifera* and 40% groundnut hulls **Table 1**.

Table 1. Proximate analysis of the experimental feed

Sample type	D.M%	Ash%	C.P%	E.E%	C.F%
A (0%) *M. oleifera*	93.20	16.528	10.979	0.8	**25.50**
B (20%) *M. oleifera*	93.40	12.419	12.457	2.4	**35.00**
C (40%) *M. oleifera*	93.60	14.743	15.202	2.6	**22.00**
D (60%) *M. oleifera*	93.60	13.887	11.824	3.2	**33.00**

C.F%; Crude Fibre Percentage, **E.E%**; Ether Extract Percentage, **C.P%**; Crude ProteinPercentage, **Ash%** ; Ash Content Percentage, **D.M%**; Dry Matter Percentage.

Blood serum analysis

Blood serum albumin (ALB) and total protein (TP)

Blood samples were taken biweekly from the external jugular vein over a three-month period at the beginning of the experiment. Samples were left to stand overnight at room temperature in 10 ml vacutainers without anticoagulant to prepare for serum analysis. Serum was then pipetted into 10 ml test tubes, centrifuged, and the supernatant was stored at -25°C for biochemical analysis. For total protein (TP) determination, reagent A (containing Copper (II) acetate, potassium iodide, sodium hydroxide, detergent) and protein standard S (Bovine albumin, traceable to Standard Reference Material 927) were used. Albumin (ALB) determination utilized reagent A (acetate buffer, bromocresol green, detergent, pH 4.1) and albumin standard S.

Macro mineral blood serum levels

Phosphorus (P) was measured using reagent RGT (Ammoniumheptamolibdate and Sulphuric acid) and a phosphorus standard. Magnesium (Mg) levels were determined using buffer R1, chromagen R2, and a magnesium standard, following methods by (Fick 1979). Calcium (Ca) was analyzed using OCC indicator R1, OCC buffer R2, and a calcium standard. Sodium (Na) and Potassium (K) levels were assessed using a spectrophotometer with a visible UV setup.

Micro mineral blood serum levels

Iron (Fe) levels were measured with reagents A and B, and an iron standard. Zinc (Zn) and Copper (Cu) levels were assessed with a stock standard solution as outlined by (Harris et al., 1954).

Milk composition

Basic composition

The proximate composition of goat milk, including moisture, fat, ash, crude fibre, crude protein, and carbohydrates, was assessed using methods from the Horwitz and Association of Official Analytical 2000.

Determination of milk pH and titratable acidity

Milk pH was determined using a pH meter as per the procedure by O'Connor 1995. While, the milk sample's titratable acidity was measured according to Horwitz and Association of Official Analytical 2000 protocols, with the formula:

$$\text{Titratable Acidity (\%)} = \frac{\text{N/10NaOH (ml)x 0.009}}{\text{Weight of milk sample}} \text{x } 100$$

Milk yield and body weight

Goats were weighed biweekly using an unequal-arm balance, and their milk yield and composition were recorded during the first three months postpartum, according to Landi et al., 2021 and Saleh et al., 2022, for body weight and milk yield/ composition, respectively.

Fertility trait measurements

Oestrus synchronization and detection

Each doe received two intramuscular injections of prostaglandin 150 µg PGF2α, with vitamin A.D.E. supplementation. Sexually experienced Nubian bucks were introduced for natural service, and behavioral signs of oestrus were observed after the second PGF2α injection. Oestrus response percentage and pregnancy were determined according to Ogunbiyi et al. 1980.

Pregnancy diagnosis

Pregnancy was diagnosed using managemental and ultrasonographic methods. Post-insemination, goats were observed for non-return rates and later confirmed via abdominal ultrasonography. Pregnancy rate, kidding rate, litter size and gestation period were recorded following parturition according to Saleh et al., 2020.

Ultrasonographic fetal measurements

Goats underwent fasting before scanning, with sufficient ultrasonic gel applied to the shaved ventral abdomen. A real-time ultrasound scanner (Canon Medical Systems, Aplio i-series ultrasonographic device, Japan) with various transducers was employed to record fetal measurements including crown-rump length (CRL), biparietal diameter (BPD) and femur length (FL).

Crown-rump length (CRL)

CRL was measured at 45 days of gestation. Measurements were taken from the most dorsal part of the fetus to the end of the sacrum.

Bi parietal diameter (BPD) and femur length (FL)

BPD was assessed at 80 days of gestation, in a specific coronal section. While, FL was measured at 80 days of gestation, identifying calcification zones.

The effect of different levels of M. oleifera leaves on birth weight (Kg)

The goats were housed in similar conditions to minimize confounding variables and were monitored throughout their gestation period. Birth weight was recorded for each kid born from the respective groups.

Statistical analysis

To ensure robust results, we conducted a comprehensive statistical analysis of the collected data. Initially, means and standard deviations were calculated to summarize the dataset. For a deeper analysis, we employed the Analysis of Variance (ANOVA) using the general linear model approach to identify significant differences among groups. In cases where significant effects were detected, Duncan's multiple range test was used to determine which specific groups differed from each other. These statistical procedures were carried out using SPSS software, version 24.0 (IBM Corp., Armonk, NY, USA), and adhered to standards established since its introduction in 1998.

Results and Discussion

Blood serum ALB and TP

Table 2 presents data on blood serum ALB and TP in Nubian goats fed varying levels of *M. oleifera*. Despite significant differences among the groups ($p < 0.05$), the highest ALB values were observed in groups C (26.27±5.49 g/dL) and B ((26.17±8.94 g/dL), whereas the lowest values appeared in groups A (23.27±12.2 g/dL) and D (22.97±11.0 g/dL). Similarly, TP levels were highest in group C (62.55±14.9 g/dL), with the lowest in group C (51.65±24.9 g/dL), and moderate levels in groups B (59.92±15.09 g/dL) and A (54.01±23.77). These findings align with previous studies, such as Meel et al., 2018 on Sirohi goat, Kholif et al., 2016 and Babeker and Abdalbagi, 2015 on Nubian goat, Leitanthem et al., 2022 on goat kids and Selim et al., 2021 on Rabbits, indicating that the levels of blood serum TP and ALB observed here are consistent with established norms in similar ruminant studies. The consistency in these data across different studies suggests that *M. oleifera* supplementation did not significantly alter protein metabolism, maintaining a baseline established by historic norms in livestock nutrition.

Table 2. Mean blood serum ALB and TP of Nubian goats fed on different levels of *M. oleifera* leaves

Parameter	Mean ± SD				Overall mean
	Group A	Group B	Group C	Group D	
ALB (g/dL)	23.27±12.2^{b}	26.17±8.94^{a}	26.27±5.49^{a}	22.97±11.0^{c}	24.66±10.03
TP (g/dL)	54.01±23.77^{b}	59.92±15.09^{ab}	62.55±14.9^{a}	51.65±24.9^{c}	57.03±20.45
No. of Samples	55	55	59	51	220

Values within different superscripts in the same row are differ significantly ($P < 0.05$).

Macro mineral blood serum levels

The average macro mineral blood serum values of the goats, outlined in **Table 3**, showed significant differences across groups ($p < 0.05$). Ca levels peaked in group C (8.47±3.11 mg/dL), while lower levels were noted in groups A (7.89±3.21 mg/dL), B (7.53±4.26 mg/dL) and D (7.12±3.97 mg/dL). Significant trends were seen in P concentrations, with group C showing the highest concentration (4.62±1.98 mg/dL). K and Mg levels also showed significant variation, with notable higher concentrations in group C. However, Na levels varied significantly ($p < 0.05$), with groups C and B displaying the highest values (248.19 mg/dL and 240.83 mg/dL, respectively). Aligning with prior reports for ruminants (Al Mufarji et al., 2023; Kekana et al., 2019; Singh, 2021; Wankhede et al., 2022). The slightly lower Ca levels (7.12 to 8.47 mg/dL) compared to previous studies suggest potential dietary influences, perhaps from the *M. oleifera* supplementation or other factors. Meanwhile, Mg levels were similar to recommended values (Council, 2007), supporting their consistency across different dietary conditions. Na levels were lower than reported norms (Council, 2007), potentially reflecting variations in dietary salt provision. These macromineral observations underscore the importance of tailoring diets to meet specific nutrient requirements for optimal health and productivity, emphasizing the role of *M. oleifera* as a supplementary feed component.

Table 3. Mean values of macro mineral blood serum levels of Nubian goats fed on different levels of *M. oleifera* leaves

Parameter	Mean ± SD			
	Group A	Group B	Group C	Group D
Ca (mg/dl)	7.89±3.21^{b}	7.53±4.26^{b}	8.47±3.11^{a}	7.12±3.97^{b}
P (mg/dl)	3.93±2.198^{c}	3.88±2.56^{c}	4.62±1.98^{a}	4.099±1.76^{b}
K (mq/dl)	9.83±2.89^{c}	10.18±3.45^{b}	12.13±2.90^{a}	11.66±3.77^{ab}
Mg (mg/dl)	1.95±1.27^{b}	1.99± 1.32^{b}	2.33±0.95^{a}	2.29±1.39^{a}
Na (mg/dl)	207.67±38.23^{bc}	240.83±41.05^{ab}	248.19±39.56^{a}	199.18±29.40^{c}
No. of samples	35	35	39	35

Values within different superscripts in the same row are differ significantly ($P < 0.05$).

Micro mineral blood serum levels

The micro-mineral content, summarized in **Table 4**, revealed significant differences across zinc and Fe concentrations between groups ($p < 0.05$), though group C exhibited the highest Zn levels. Cu concentrations showed significant variance with higher values in groups C and B (approximately 0.122 meq/L; 0.121 meq/L) compared to group A (0.108 meq/L). in line with previous findings in goats (Liu and Shen, 2024; Solaiman et al., 2024), reinforcing the observation that Cu levels remain within acceptable ranges across diverse environments and diets. Zn concentrations observed (0.099 to 0.114 mg/dL) correspond with earlier studies (Hayuningtyas et al., 2024), while Fe levels (2.22 mg/dL) were higher than some past research but still within a normal range (Khan, 2003). These micro-mineral profiles suggest that *M. oleifera* does not significantly alter the balance of essential minerals, despite its rich micronutrient content, indicating its compatibility as a dietary supplement in livestock without negatively impacting essential mineral homeostasis.

Table 4. Mean values of micro-mineral blood serum levels of Nubian goats fed on different levels of *M. oleifera* leaves.

Parameter	Mean ± SD				Overall mean
	Group A	Group B	Group C	Group D	
Zn (meq/L)	0.11±0.01^{a}	0.10±0.02^{ab}	0.11±0.01^{a}	0.09±0.04^{b}	0.11±0.02
Fe (meq/L)	2.31±0.80^{ab}	2.22±1.01^{b}	2.32±0.70^{a}	2.04±0.89^{c}	2.22±1.00
Cu (meq/L)	0.108±0.09^{c}	0.121±0.07^{ab}	0.122±0.09^{a}	0.120±0.09^{b}	0.118±0.08
No. of samples	35	35	39	35	144

Values within different superscripts in the same row are differ significantly ($P < 0.05$).

Basic composition of goat milk

Table 5 illustrates the basic composition of Nubian goat milk. PH, acidity, moisture content, and ash levels showed significantly ($p < 0.05$) across groups, with variations in fat values being highest in group C and lowest in group D. Protein content remained uniform among the groups, as did the carbohydrate content, with group C recording the highest carbohydrate value. consistent with findings by Park et al., 2000. Protein content (3.94% to 4.21%) was slightly higher than reported by Jenness, 1980, possibly indicating enhanced nutritional quality. Ash, carbohydrate, and moisture content were largely consistent with previous reports (Kholif et al., 2015). These outcomes suggest that while *M. oleifera* drastically change milk composition, it maintains or potentially enhances certain nutritional criteria, affirming its role as a sustainable feed option that could promote dairy productivity without adverse impacts on milk quality.

Table 5. Mean values of basic composition of goat milk (%) of Nubian goats fed on different levels of *M. oleifera* leaves.

Parameters	Mean ± SD			
	Group A	Group B	Group C	Group D
PH	6.55± 0.17^{c}	6.60±0.079^{b}	6.65±0.11^{a}	**6.55±0.13^{c}**
Acidity	2.68±0.15^{ab}	2.43±0.12^{ab}	2.93±0.397^{a}	**2.18±0.38^{c}**
Moisture (%)	88.11±0.52^{b}	88.24±0.23^{ab}	88.41±0.34^{a}	**87.23±0.199^{c}**
Ash (%)	0.39±0.018^{b}	0.40±0.12^{ab}	0.41±0.03^{a}	**0.38±0.096^{c}**
Fat (%)	2.31±0. 59^{b}	2.68±0.34^{ab}	2.71±0.49^{a}	**2.28±0. 24^{c}**
Protein (%)	4.00±0.52^{b}	4.15±0.084^{b}	4.21±0.45^{a}	**3.94±0.37^{c}**
Carbohydrate (%)	4.64±0.38^{c}	4.95±0.61^{b}	5.01±0.56^{a}	**4.63±0.45^{c}**

Values within different superscripts in the same row are differ significantly ($P < 0.05$).

Milk yield and body weight

Data in **Table 6** demonstrates milk yield and body weight, highlighting significant differences in milk yield ($p < 0.05$). Groups C achieved the highest yields, with groups D showing comparatively lower yields. Body weight a slight increase ($p < 0.05$) was noted in group C across other groups, corroborating findings by Kholif et al., 2015; Mataveia et al., 2019; Kholif et al., 2019 and Afzal et al., 2022 which noted *M. oleifera* potential to enhance rumen function and microbial output. Body weight exhibited significant changes ($p < 0.05$), corroborating findings from Sultana et al., 2015 as well as other research focusing on the growth performance enhanced by *M. oleifera*. These results indicate that the advantages of *M. oleifera* supplementation may be more pronounced in lactational performance rather than in general growth metrics. This observation underscores the potential of *M. oleifera* as a strategic tool in dairy goat management, suggesting that its incorporation into feeding regimens could optimize milk production and overall herd productivity. By prioritizing lactation improvements, farmers can enhance the efficiency of their operations, ensuring better health and productivity for dairy goats, while also potentially increasing profitability.

Table 6. Mean values of milk yield (L/day) and Body weight (Kg) of Nubian goats fed on different levels of *M. oleifera* leaves.

Parameter	Mean ± SD			
	Group A	Group B	Group C	Group D
Milk yield (L/day)	0.77±0.32^{b}	0.99±0.39^{ab}	1.01±0.35^{a}	**0.74±0.34^{c}**
Body weight (kg)	21.17±10.109^{b}	22.64±4.85^{ab}	23.23±3.75^{a}	**20.39±10.81^{c}**

Values within different superscripts in the same row are differ significantly ($P < 0.05$).

Fertility traits

Presented in **Table 7**, fertility outcomes exhibited significant differences in oestrus response ($p < 0.05$), with groups B and C achieving a 100% response rate. Conception rates (100%) and litter sizes were higher ($p < 0.05$) in groups B and C. These results align with studies by Romano, 1998 and Kusina et al., 2000, proving effective synchronization and enhanced reproductive readiness with *M. oleifera* supplementation. Conception rates remained constant at 100%, while litter sizes were similar to previous findings, indicating robust fertility outcomes regardless of dietary variations. The insight into oestrus synchronization strategies could inform improved breeding practices in goats, particularly integrating natural feed supplements like *M. oleifera* to bolster reproductive efficiencies.

Table 7. Mean values of fertility traits of Nubian goats fed on different levels of *M. oleifera* leaves.

Parameter	Mean ± SD			
	Group A	Group B	Group C	Group D
Oestrus response (%)	80^{ab}	100^{a}	100^{a}	**60^{b}**
Conception rate (%)	100^{a}	100^{a}	100^{a}	**100^{a}**
Litter size	1.30±0.55^{b}	1.40±0.55^{ab}	1.50±0.58^{a}	**1.00±0.00^{c}**
Birth weight/Kg	2.38±0.32^{b}	2.40±0.91^{ab}	2.75±0.25^{a}	**1.95±0.65^{c}**
Gestation/day	152.50±2.89^{b}	153.60±3.36^{ab}	155.33±0.58^{a}	**151.20±5.45^{c}**

Values within different superscripts in the same row are differ significantly ($P < 0.05$).

Ultrasonographic fetal measurements

The fetal measurements, as shown in **Table 8**, illustrate FL, BPD, and CRL at various gestation days. Group C displayed the highest mean FL measurements at 80 days, while CRL were longest in group B at 45 days of gestation, these differences were statistically significant ($p < 0.05$), they provide insight into fetal development under the diet regimen, closely mirroring the results of Abdelghafar et al., 2010; Yadav, 2021 and Gouda et al., 2021. These metrics suggest that *M. oleifera* supplementation impact fetal development, thus providing a valuable baseline for concluding that *M. oleifera* enhanced diets can support normal gestational progress in goats. The integration of such nutritional strategies could refine prenatal care, ensuring optimal developmental outputs while maintaining economic and environmental sustainability in goat husbandry.

Table 8. Mean values of foetal femur length (FL), Biparietal diameter (BPD) and Crown rump length (CRL) of Nubian goats fed on different levels of *M. oleifera* leaves

Parameters	Mean ± SD			
	Group A	Group B	Group C	Group D
FL (cm)	2.08±0.17^{b}	2.19±0.41^{ab}	2.72±0.59^{a}	**2.06±0.35^{c}**
BPD (cm)	2.52±1.14^{b}	2.47±0.52^{ab}	2.73±0.32^{a}	**2.42±0.22^{c}**
CRL (cm)	2.46±2.25^{b}	2.78±2.01^{a}	2.70±2.34^{ab}	**2.16±2.58^{c}**

Values within different superscripts in the same row are differ significantly ($p < 0.05$).

The effect of different levels of M. oleifera on birth weight (Kg)

The results of the study examining the effect of different levels of *M. oleifera* leaves on the birth weights of Nubian goats are presented in **Table 9**. For single males, the mean birth weights across the groups varied, with group A having a mean of 3.02±0.30 kg, group B at 3.38±0.40 kg, group D at 3.00±0.25 kg, and group C showing the highest mean of 3.50±0.35 kg. The comparable birth weights of single males in groups A and D, along with the elevated weights in groups B and C, indicate a possible dose-response correlation suggesting that higher *M. oleifera* supplementation may lead to increased birth weights in single males. Specifically, Group A had a mean birth weight of 3.02±0.30 g, while Group D weighed 3.00±0.25 g, in contrast to the higher weights found in Groups B and C, which were 3.38±0.40 g and 3.50±0.35 g, respectively. In single females, the mean birth weights were

relatively uniform across the groups, with group A and C both at 2.63±0.18 kg, suggesting no significant effect of *M. oleifera* supplementation within the studied range on female singletons. However, for twins, significant variation was observed with groups B and C showing the highest mean of 2.50±0.35 kg, group C at 1.67±0.53 kg, group B at 1.25±0.00 kg, and group A at 1.63±0.88 kg, indicating potential differential effects based on the varying levels of *Moringa* supplementation.

Table 9. Mean Values of Birth Weight (Kg) of Nubian Goats Fed on Different Levels of *M. oleifera* leaves

Parameter	Mean ± SD			
	Group A	Group B	Group C	Group D
Birth weight of single males	3.02±0.30^{b}	3.38±0.40^{ab}	3.50±0.35^{a}	3.00±0.25^{c}
Birth weight of single females	2.62±0.18	2.62±0.14	2.62±0.18	2.63±0.35
Birth weight of twins	1.63±0.88^{b}	2.50±0.35^{a}	2.51±0.71^{a}	1.52±0.00^{c}

Values within different superscripts in the same row are differ significantly ($P < 0.05$).

Conclusions

Feeding Nubian goats *M. oleifera* leaves at varying inclusion levels demonstrated a significant impact on a range of physiological parameters, including blood serum albumin, total protein, and both macro and micro minerals. Notably, there were increases in copper and sodium levels at medium inclusion rates of *M. oleifera*. Moreover, milk yield was positively correlated with the amount of *M. oleifera* provided, suggesting that higher supplementation can enhance milk production. In terms of reproductive performance, various fertility traits were influenced by the dietary *M. oleifera*; however, improvements in oestrus response were particularly notable at inclusion rates of 20% and 40%. This finding suggests that certain levels of *M. oleifera* can optimize reproductive health and efficiency in Nubian goats. Additionally, differences in fetal measurements observed via ultrasound further underscore the potential benefits of *M. oleifera* on reproductive outcomes. Overall, *M. oleifera* emerges as a promising dietary supplement for goat nutrition, effectively enhancing milk yield while maintaining reproductive health. Given these positive results, further studies should investigate the effects of *M. oleifera* on male fertility, expanding our understanding of its potential benefits across different aspects of goat husbandry. This research could pave the way for implementing *M. oleifera* as a strategic supplement to boost overall productivity in goat farming systems.

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Declarations

Ethical Approval Certificate

All animal experiments adhered to the guidelines approved by the Animal Care and Use Committee (IACUC) of University of ALBUTANA, Sudan. 7 April 2023 approval date, and number: 202302007

Author Contribution Statement

H.M.H.: conceptualization, methodology, software, data curation, writing—original draft. M.A.M., **A.E.A.M.,** A.A.S., M.O.A.E., S.Y.A., & E.A.B.: writing—review and editing. M.W.: Funding acquisition, Project administration, Supervision, Visualization. All authors contributed to the article and approved the submitted version.

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ID: 491

Sensory and Texture Profile Analyze of Bulgur Samples

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Abstract

Sensory and textural characteristics have a great influence on consumers' purchasing and consumption decisions and the food product should have a certain level of sensoral and textural profile to be preferred by the consumers. The main aim of this study was to compare the sensory and texture profile of the bulgur samples produced by two pea cultivars and commercial bulgur as a control sample. The hardness, adhesiveness, springiness, cohesiveness, gumminess, chewiness, and resilience characteristics were determined to assess the texture profile of the bulgur samples. There were statistically significant differences between samples in terms of hardness ($p<0.05$). Hardness values of bulgur samples produced using cv. Deren and Irmak-01 were 2132 and 1801 g, respectively, while the value of the control bulgur sample was 682 g. In terms of adhesiveness and springiness, the differences between samples were not statistically significant ($p>0.05$).In terms of cohesiveness, gumminess, chewiness and resilience values, cv. Deren had the highest values ($p<0.05$). Sensory analyses of bulgur samples were conducted by fifteen panelists. Panelists were asked to score the cooked bulgur samples in terms of appearance, color, smell, texture, taste and overall acceptability. They were evaluated with the 9-point hedonic scale ranging from 1 = Dislike extremely and 9 = Like extremely. The sensory profile of pea bulgur samples produced with cv. Deren and Irmak-01 had lower scores as compared to the control bulgur (7.47) in all characteristics with an overall acceptability value of 4.47 and 4.43, respectively. The color, smell and taste values of the bulgur produced with cv. Irmak-01 had slightly higher scores rather than those of cv. Deren (4.67), however, the differences were not statistically significant ($p>0.05$). It can be concluded that the sensory profile of pea cultivars had almost similar sensory profiles. Hovewer, textural profiles of bulgur samples varied depending on the variety.

Key Words: *Bulgur, Food Legumes, Pulses, Sensory, Texture*

ID: 493

Responses of Some Almond (*Prunus dulcis*) Varieties to Drought Stress

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Abstract

Drought stress, which has become more pronounced due to global climate change, is a significant factor limiting agricultural sustainability. One of the necessary steps to address this issue is the use of drought-tolerant plants. In this study, the drought tolerance of some newly developed almond varieties, such as Makako, Marinada, and Vairo, was determined with the help of morphological and physiological markers. The plants, grafted onto Garnem rootstocks and grown in 18-liter pots, were subjected to deficit irrigation treatments (T1: 100% irrigation (control); T2: 50% irrigation; T3: 25% irrigation) for two years to induce drought stress. At the end of the study, it was found that fresh and dry plant weights, membrane stability index (MSI), leaf water potential (LWP), CO_2 assimilation rate, and stomatal conductance were significantly affected by drought stress. The Marinada variety exhibited the highest fresh and dry plant weights. However, in terms of MSI, LWP, CO_2 assimilation, and stomatal conductance, the Vairo variety showed greater drought tolerance. As a result, the drought tolerance and sensitivity of the grafted varieties on Garnem rootstock were evaluated. However, it is believed that detailed biochemical analyses and field studies are necessary to reach a definitive conclusion.

Key Words: *Drought stress, Almond, Morphological, Physiological, Tolerance*

ID: 494

Kuraklık ve Sıcaklık Stresinin Patates Bitkisi Üzerine Etkileri

Tuğba Özkan

Patates Araştırma Enstitüsü Müdürlüğü

Özet

Küresel iklim değişikliği, tarım sektörünü önemli ölçüde etkileyen bir faktördür. İklim değişikliği ile birlikte kuraklık olaylarının sıklığı ve şiddeti artmaktadır, bu da tarımsal üretimi ve gıda güvenliğini tehdit etmektedir. İklim değişikliği nedeniyle artan kuraklık şiddeti ve sıklığı, patates üretimini olumsuz etkilemektedir. Bunun yanı sıra küresel iklim değişikliği; sıcaklık ve CO_2 seviyeleri, zararlılar ve hastalıklar, toprak ve su kaynakları ve bölgesel farklılıklar gibi faktörlerde patates verimini ciddi anlamda azaltır. Artan sıcaklıklar, değişen yağış zamanları ve miktarları tarımsal üretimi ve gıda güvenliğini tehdit etmektedir. Bitkiler abiyotik streslere karşı farklı mekanizmalar geliştirebilirler. Bu streslerle mücadelede fotosentez, biyokimyasal yollar ve stres toleransı gibi çeşitli mekanizmaları kullanırlar. Patates suya duyarlı bir bitki olduğundan kuraklık stresinde verim ve kalite olumsuz etkilenir. Bu çalışmada iklim değişikliğinin tarıma etkisi, kuraklık ve sıcaklık streslerinin patatese etkileri değerlendirilmiştir.

Anahtar kelimeler: *İklim Değişikliği, Kuraklık-Sıcaklık Stresi, Verim, Kuraklığa Tolerans*

ID: 495

Determination of Yield and Quality Characteristics of Immortal Flower (*Helichyrsum italicum* (Roth) G. Don fil.) Plant Conditions at Different Growth Periods in Çukurova Conditions

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Abstract

This study, which was conducted to determine the yield and quality characteristics of Immortelle ((Helichyrsum italicum (Roth) G. Don fil.)) plant in different development periods under Çukurova conditions, was conducted at the research area of Çukurova University, Faculty of Agriculture, Department of Field Crops in 2021-2022. Three different development periods were selected as the harvesting time of the immortelle plant: beginning of flowering, full flowering and post-flowering. As a result of the research, according to the harvesting time, the average plant height was 37.43-47.80 cm, fresh herb yield was 534.37-784.83 kg/da, dry herb yield was 139.50-361.32 kg/da, fresh flower yield was 65.24-203.80 kg/da, dry flower yield was 25.66-111.64 kg/da, essential oil ratio in flower (0.30-0.88%), flower essential oil yield was 0.22-0.4 l/da. It was found that the main components of the essential oil were α-pinene, γ-curcumene, italidion I, neryl acetate, italidion II, caryophyllene, β-selinene and the ratios of these components changed according to the harvest time of the plant. As a result of the research, it was found that the most suitable harvest time for H. italicum was the beginning of flowering and full flowering. However, further research is needed to determine the appropriate time for the beginning of flowering.Key Words*: Helichyrsum italicum,* Immortal Flower, development period, essential oil, yield and quality

Çukurova Koşullarında Ölmez Çiçek (*Helichyrsum italicum*) Bitkisinin Farklı Gelişme Dönemlerinde Verim ve Kalite Özelliklerinin Belirlenmesi

Özet

Çukurova koşullarında ölmez çiçek (*Helichyrsum italicum* (Roth) G. Don fil.) bitkisinin farklı gelişme dönemlerinde verim ve kalite özelliklerinin belirlenmesi amacıyla yapılan bu çalışma 2021-2022 yıllarında Çukurova Üniversitesi Ziraat Fakültesi, Tarla Bitkileri Bölümü araştırma alanına kurulmuştur. Ölmez çiçek bitkisinde hasat zamanı olarak çiçeklenme başlangıcı, tam çiçeklenme ve çiçeklenme sonrası olmak üzere üç farklı gelişme dönemi seçilmiştir. Araştırma sonucunda hasat zamanlarına göre bitki boyu ortalamaları 37.43-47.80 cm, taze herba verimleri 534.37-784.83 kg/da, kuru herba verimleri 139.50-361.32 kg/da, taze çiçek verimleri 65.24-203.80 kg/da, kuru çiçek verimleri 25.66-111.64 kg/da, çiçekte uçucu yağ oranı (% 0.30-0.88), çiçek uçucu yağ verimleri 0.22-0.4 l/da arasında değişmiştir. Uçucu yağın ana bileşenleri α-Pinene, γ-Curcumene, italidion I, Neryl acetate, italidion II, Caryophyllene , β-Selinene olduğu ve bu bileşenlerin oranlarının bitkinin hasat zamanına göre değişim gösterdiği belirlenmiştir. Araştırma sonucunda *H.italicum*'da en uygun hasat zamanının çiçeklenme başlangıcı ve tam çiçeklenme dönemleri olduğu belirlenmiştir. Bununla birlikte, çiçeklenme başlangıcında da uygun zamanı belirlemek için daha fazla araştırma yapılması gerekmektedir.

Anahtar Kelimeler: *Helichyrsum italicum, Ölmez Çiçek, gelişme dönemi, uçucu yağ, verim ve kalite*

Giriş

Bitkiler, insanların yaşamında her zaman çok önemli bir yere sahip olmuştur ve insanoğlunun varoluşundan bu yana bitkileri ihtiyaç duydukları her alanda (beslenme, hastalıkların tedavi edilmesi, barınma, yakacak) kullanmışlardır. Tıbbi ve aromatik bitkiler insanların daha sağlıklı ve kaliteli bir yaşam sürmeleri açısından önemli olan sekonder metabolit (alkaloitler, terpenoitler ve fenolikler) olarak adlandırılan biyoaktif etken maddeler içerirler (Kırıcı ve ark., 2020). Sekonder metabolitler başta ilaç, gıda katkı maddeleri, aroma verici, kozmetik ve endüstriyel açıdan benzersiz kaynaklardır (Ramakrishna ve Ravishankar, 2011). Dünyadaki 20.000 bitki türünden elde edilen 4000 kadar bitkisel drogunun tıbbî amaçlarla kullanıldığı, Türkiye'de yetişen 12.000'e yakın bitki taksonundan 500 tanesinin tıbbi bitki olduğu bilinmektedir (Nohutçu ve ark., 2019). Ekonomik değeri yüksek tıbbi ve aromatik bitkilerden özellikle uçucu yağ içerenler gün geçtikçe daha fazla önem kazanmaktadır. Uçucu yağlara olan talep her geçen yıl artmakta ve ekonomik boyutta da önemli bir sektör olarak gelişmektedir. Uçucu yağlar ve rezinoitler, parfümeri, kozmetik vd. dünya ihracat değerleri 2001 yılında 34.1 milyar dolar iken 2019 yılına gelindiğinde beş kat artarak 150.7 milyar dolara ulaşmış, 2021 yılında ise 157,6 milyar dolar ile tıbbi ve aromatik bitkiler ihracatında en fazla artışa sahip olan ürün grubu olmuştur (Boztas ve ark., 2021; Kırıcı, 2022). Bu bitkilerden biri de ilaç, kozmetik ve parfüm endüstrisinde popülaritesi her geçen gün artan *Helichrysum italicum*

(Roth) G. Don fil.'dir. Ülkemizde *Helichrysum* cinsine "alay çiçeği, altınbaşak, altın çiçeği, altın otu, arı çiçeği, bozoğlan, herdemtaze, kovan otu, kudama, mantı çiçeği, yayla çiçeği, yayla gülü" gibi pek çok isim verilmiştir, bununla beraber, genel olarak ölmez çiçek adıyla anılır, Adana ve Kadirli (Osmaniye)'de yöre halkı '' Mantuvar '' ismini kullanmaktadır (Baytop, 1997; Eroğlu, 2018). *H. italicum* çiçekleri gıda sektöründe, unlu mamuller ve alkolsüz içeceklere çeşni ve tat vermek için kullanılmakta, ayrıca cildi yenileme özelliği ile kozmetik sektörünün gözde bitkileri arasında yer almaktadır (Baytop, 1999, Antunes Viegas ve ark., 2014). Geleneksel olarak halk hekimliğinde idrar yolu enfeksiyonları, böbrek hastalıkları ve böbrek taşı, öksürük, bronşit, ishal, dezenfektan madde olarak, yara iyileştirici, baş ağrısı, gribal enfeksiyonlar, safra kesesi, mide, karaciğer ve bağırsak hastalıklarında, sarılık, diyabet, kalp, diş ve göz hastalıkları, bağırsak parazitleri için kullanılmaktadır (Akaberi ve ark., 2021). Yapılan çalışmalar ölmez çiçeğin içerdiği fitokimyasalların antimikrobiyal, antiinflamatuar, antioksidan, antiviral, antikanser , böcek öldürücü ve kovucu aktiviteler de dahil olmak üzere çeşitli biyolojik özelliklere sahip olduğunu göstermiştir (Arbeiter ve ark.,2021). *H.italicum* bitkisinin çiçekleri ve toprak üstü kısımları uçucu yağ ve fenolik bileşikler açısından zengindir. Ölmez çiçek uçucu yağı bileşimi çok fazla farklılık göstermekle birlikte içerdiği başlıca biyoaktif bileşikler monoterpenlerden α-pinen, nerol, neryl asetat ve neryl propianoat, seskiterpenlerden α–selinen, β-selinen, γ-curcumen, nerolidol 'dur (Furlan ve Bren, 2023). Korsika, Sardunya ve Toskana Adalarından hasat edilen *H. italicum* bitkisinin uçucu yağının ana bileşeni neryl asetatdır ve bundan dolayı Akdeniz bölgesinde özellikle Korsika Adası için ekonomik bir öneme sahiptir (Bianchini ve ark., 2009; Bianchini ve ark., 2001; Guinoiseau ve ark., 2013; Leonardi ve ark., 2013).

Ölmez çiçekte verim bitkilerin yaşına ve bölgenin ekolojik koşullarına bağlı olarak değişir, üçüncü ve sekizinci yıllar arası en verimli dönemidir, bu yıllarda 7 ila 8 t/ha taze çiçek ve 3.5 ila 4 ton/ha kuru çiçek elde edilip, uçucu yağ verimi 0.8-1.2 kg/da arasında değişir (Mucalo, 2015). Batı Akdeniz Kalkınma Ajansı (BAKA) tarafından hazırlanan 'Ölmez çiçek (*H. italicum*) tarımı ve endüstrisi' adlı fizibilite raporuna göre taze çiçek veriminin ikinci yıl (350 kg/da), üçüncü yıl (550 kg/da) olduğunu ve en yüksek taze çiçek veriminin beş, altı ve yedinci yıllarda (1000 kg/da) elde edildiğini bildirmişlerdir. Ölmez çiçeğin uçucu yağ oranının çok düşük olduğunu (%0.12-0.35) ve yaklaşık 700-1000 kg çiçekten bir kilogram uçucu yağ elde edildiğini, uçucu yağ veriminin ise (0.8-1.2 kg/ da) arasında değiştiğini belirtmişlerdir (BAKA, 2021). Sırbistan'da yetiştirilen *H.italicum* bitkilerinin ikinci yılında yapılan ilk hasatında bitkilerin boylarının tomurcuklanma aşamasında 35.2 cm-37.2 cm, çiçeklenme döneminde 39.4 cm - 42.2 cm olarak belirtmişlerdir. Biyomas verimini 564 kg/da-538 kg/da olarak açıklamışlardır. Uçucu yağ oranını % 0,148-%0.143 ve uçucu yağ veriminin 0.8 kg/da-0.7 kg/da olduğunu açıklamışlardır (Miloradović, 2018).

Bu araştırmada ekonomik öneme sahip olan Ölmez Çiçek (*Helichyrsum italicum*) bitkisinin Çukurova Koşullarında farklı gelişme dönemlerinde verim ve kalite özelliklerinin belirlenmesi amaçlanmıştır.

Materyal ve Yöntem

Materyal olarak kullanılan ölmez Çiçek (*H. italicum*) fideleri ticari bir firmadan temin edilmiştir. Araştırma Ç.Ü. Ziraat Fakültesi Tarla Bitkileri Bölümü Araştırma ve Uygulama Alanında (Rakım 34 m) 2021-2022 yıllarında iki yıl süreyle yürütülmüştür. Hasat zamanları olarak üç gelişme dönemi (çiçeklenme başlangıcı, tam çiçeklenme ve çiçeklenme sonu/solgun çiçek) seçilerek, tesadüf blokları deneme desenine göre 3 tekrarlamalı olarak kurulmuştur. Toplam deneme alanı 260 m^2 olup, her bir tekerrür 6 m×13 m (78 m^2), sıra arası 100 cm (1 m), sıra üzeri 40 cm (0,4 m) olup, 13 sıra, her bir sırada 15 bitkiden oluşmuştur. Her bir tekerrürde 195 bitki, tüm deneme alanında ise 585 bitkiden oluşmuştur. Fideler 06.04.2021 tarihinde deneme alanına şaşırtılmış, dikildikten sonra can suyu verilmiş, daha sonra toprak nemine bağlı olarak sulanmıştır. Bitkilere iki defa dekara 2 kg olmak üzere %46 üre gübresi uygulanmıştır. Deneme alanında görülen yabancı otlar el çapası ile uzaklaştırılmıştır. İlk biçim 3 Eylül 2021 tarihinde 5 cm yükseklikten yapılmıştır. Ancak birinci yıl tesis yılı olarak kabul edildiğinden ilk biçim değerleri kullanılmayıp ikinci yıl verileri değerlendirilmiştir. İkinci yıl kenar tesiri çıkartılarak gerekli ölçümler yapıldıktan sonra; çiçeklenme başlangıcı 10 Mayıs 2022, tam çiçeklenme dönemi 09 Haziran 2022, çiçeklenme sonrası 26 Haziran 2022 tarihlerinde elle hasat makası kullanarak yapılmıştır. Her bir hasat zamanında bitki boyu değerleri alınmış, daha sonra bitkiler toprak yüzeyinden 10 cm yukarıdan biçilmiştir. Hasat edilen bitkiler gerekli tartım işlemlerinden sonra herba ve çiçek verimleri için gerekli örnekler alınarak oda sıcaklığında gölgede kurutulmuştur.

Su buharı distilasyonu yöntemi ile elde edilen uçucu yağların bileşenleri Çukurova Üniversitesi Merkez Araştırma Laboratuvarında GC/MS yöntemi ile saptanmıştır. Analiz Agilent Marka 7890B GC, 7010B MS sistemi ile belirlenmiştir. Hazırlanan örnekler DB-Wax (60 m x 0.25mmi.dx 0.25 µm, J&W Scientific-Folsom, USA) kapiler kolonuna 1uL enjekte edilmiştir. Enjeksiyon sıcaklığı 250 °C, kolon sıcaklığı 40 °C'de başlatılmış dakikada 3 °C artırılarak 240 °C'ye ayarlanmıştır. Taşıyıcı gaz olarak He kullanılmıştır. Elektron enerjisi 70 eV ve kütle aralığı ise 30-600 m/z'dir. Split oranı 1:20 dir. Ayrılan bileşenler NIST14L kütüphanesinde karşılaştırma yapılarak belirlenmiştir.

Elde edilen verilere JMP istatistik paket programı kullanılarak tesadüf blokları deneme desenine göre varyans analizi uygulanmıştır. Elde edilen ortalamalar %5 ve %1 önem düzeyine göre ANOVA analizi yapılarak EGF testine göre belirlenmiştir.

Bulgular ve Tartışma

Bitki Boyu

Çukurova Koşullarında yetiştirilen *H. italicum* bitkisinin farklı gelişme dönemlerinde hasat edilmesiyle elde edilen bitki boyuna ait veriler istatistiksel yönden önemli bir fark bulunmamıştır. *H. italicum* bitki boyu değerleri ortalama 37.43-47.80 cm arasında değişmiştir. En düşük bitki boyu çiçeklenme başlangıcında yapılan hasatta 37.43 cm olarak elde edilirken, en yüksek değer 47.80 cm ile çiçeklenme sonrası yapılan hasattan alınmıştır. Araştırma sonuçları Miloradović, (2018) 35,2-42,2 cm ve Tomičić ve ark., (2022) 'ın 23,4-49,5 cm elde ettiği değerlerle benzerdir.

Taze ve Kuru Herba Verimleri

Farklı hasat zamanlarında elede edilen taze herba verim değerleri arasında %1 düzeyinde önemli farklılık bulunmuştur (Çizelge 1). Taze herba verimi 534.37-784.83 kg/da arasında değişmiştir. En yüksek taze herba verimi 784.83 kg/da ile çiçeklenme sonrası dönemde yapılan hasattan elde edilirken, tam çiçeklenme döneminde 639.67 kg/da verim elde edilmiş, en düşük verim ise 534.37 kg/da ile çiçeklenme başlangıcı döneminde yapılan hasattan elde edilmiştir. Araştırma sonuçlarımız Baniček (2019) 700-800 kg/da ve Čagalj ve ark. (2019)'555,5 kg/da nın sonuçları ile uyumlu olurken Ivankovic ve ark (2016) 243,1-361,6 kg/da sonucunda yüksek çıkmıştır.

Kuru herba verimi üzerine hasat dönemlerinin etkisi varyans analizi sonucunda %5 düzeyinde önemli bulunmuştur (Çizelge 1). Kuru herba verimi 139.5-361.32 kg/da arasında değişmiş, en yüksek kuru herba verimi yaş herba verimine paralel olarak 361.32 kg/da ile çiçeklenme sonrası dönemde, en düşük 139.50 kg/da ile çiçeklenme başlangıcı döneminde yapılan hasattan elde edilmiştir. Taze herba veriminde olduğu gibi kuru herba veriminde de bitkinin gelişim dönemi ilerledikçe verim değerleri artmıştır. Miloradović (2018), yaş herba kütlesinin kurutulmayla yaklaşık %65 azalarak kuru herba verim değerini verdiğini belirtmişlerdir. Benzer şekilde taze herba verimlerinin çiçeklenme başlangıcında %26,10, tam çiçeklenme %46,08 ve çiçeklenme sonrası %53,94 oranında azaldığı saptanmıştır. Herba verimlerinde elde edilen farklılıkların nedeni bitkinin yaşı, yetiştiği bölgenini iklim koşulları, bitki dikim sıklığı gibi birçok faktörden kaynaklanabilmektedir (Ivanković ve ark., 2016; Matin ve ark., 2021; Miloradović, 2018; Mucalo, 2015).

Taze ve Kuru Çiçek Verimi

Farklı gelişme dönemlerinde elde edilen taze çiçek verimi değerleri arasında varyans analizi sonucunda %5 düzeyinde önemli farklılık bulunmuştur. Araştırma da taze çiçek verimi 65.24-203.80 kg/da arasında değişmiştir. En yüksek taze çiçek verimleri çiçeklenme sonrası (203.80 kg/da) ve tam çiçeklenme döneminde yapılan hasattan (203.14 kg/da) elde edilmiş, en düşük verim ise çiçeklenme başlangıcı döneminde yapılan hasattan (65.24 kg/da) elde edilmiştir. İstatistiksel olarak tam çiçeklenme ve çiçeklenme sonrası hasatlardan alınan değerler arasındaki farklılık önemli olmamıştır. Batı Akdeniz Kalkınma Ajansı' nın ölmez çiçek tarım ve endüstrisi fizibilite raporuna göre bitkiden ikinci yıl 550 kg/da taze çiçek alınabildiğini, çiçek veriminin 0.5-1500 kg/da arasında değiştiğini belirtmişlerdir (BAKA, 2021). Tam çiçeklenme döneminde elde edilen 203.14 kg/da olan kuru herba verimi BAKA 'nın açıkladığı verim değerlerinin aksine düşük çıkmıştır. Mucalo (2015) verimin bitkilerin yaşına ve bölgenin ekolojik koşullarına bağlı olarak değiştiğini, üçüncü ve sekizinci yıllar arasında en fazla verimin alındığını, bu yıllarda 700-800 kg/da taze çiçek elde edilebileceğini açıklamışlardır. Bazı araştırıcılar bitki başına çiçek veriminin 16.60 g -141.3 g arasında değiştiğini belirtmektedirler (Göre ve Avcı (2022; Weglarz ve ark., 2022).

Çizelge 1. *H. italicum* bitkisinin farklı gelişme dönemlerinde elde edilen bitki boyu(cm), taze ve kuru herba verimleri (kg/da), taze ve kuru çiçek verimleri (kg/da),uçucu yağ oranı (%) ve uçucu yağ verim (l/da) değerleri

Hasat Zamanları	Bitki boyu cm	Taze herba verimi kg/da	Kuru herba verimi kg/da	Taze çiçek verimi kg/da	Kuru çiçek verimi kg/da
Çiçeklenme Başlangıcı	37.43B	534.37 C	139.50 B	65.24 B	25.66 C
Tam Çiçeklenme	43.70A	639.67 B	345.08 A	203.14 A	91.90 B
Çiçeklenme Sonrası	47.80A	784.83 A	361.32 A	203.80 A	111.64 A
EGF (%5)	5.09	29.52	67.20	59.25	16.09
C.V(%)	5.2	5.1	3.6	6.5	1.6

Kuru çiçek verimi üzerine hasat dönemlerinin etkisi varyans analizi sonucunda %1 düzeyinde önemli farklılık bulunmuştur (Çizelge 1). En yüksek kuru çiçek verimi çiçeklenme sonrası (111.64 kg/da), daha sonra tam çiçeklenme (91.90 kg/da) ve en düşük çiçeklenme başlangıcı hasatında (25.66 kg/da) olarak elde edilmiştir. Mucalo (2015), en fazla verimin alındığını üçüncü ve sekizinci yıllar arasında (350-400 kg/da) kuru çiçek elde edilebildiğini açıklamışlardır.İkinci yılda alınan kuru çiçek verimleri 25.66-111.64 kg/da arasında olup, Mucalo (2015) üçüncü yıl elde ettiği 350-400 kg/da verim değerlerinden düşük çıkmıştır. Kuru çiçek verimi taze çiçeklerin kurutulmasıyla elde edilen bir değer olduğu için sonuçlar taze çiçek verimiyle paralel olmuştur. Demirbaş ve Ateş

(2021) ölmez çiçek bitkilerinin yetiştirileceği alanın bol güneş alıyor olmasının çiçek açma performansını arttırdığını, BAKA (2021) aşırı nemli yaz sıcaklarının çiçek verimliliği ve kalitesini olumsuz yönde etkilediğini belirtmişlerdir. Burada elde edilen taze çiçek veriminin literatür değerlerinden düşük olması ekolojik faktörlerden ve bitki yaşından kaynaklandığı düşünülmektedir.

Çiçekte Uçucu Yağ Oranı

Ölmez çiçek bitkinin ticari öneme sahip kısmı olan uçucu yağı berrak, altın sarısı renk ve belirgin yoğun bir kokuya sahiptir (Peršić ve ark., 2019). *H.italicum* bitkisi çiçek başlarında, genç saplarında ve yapraklarında uçucu yağ salgılayan glandüler trikomlara sahiptir (Morone-Fortunato ve ark., 2010). *H. italicum* bitkisinin farklı gelişme dönemlerinde elde edilen uçucu yağa ait varyans analizi sonucunda hasatlar arasında %1 düzeyinde önemli farklılık bulunmuştur. En yüksek uçucu yağ oranı çiçeklenme başlangıcı %0.88, tam çiçeklenme %0.44 ve en düşük %0.30 çiçeklenme sonrası hasatında elde edilmiştir (Çizelge 2). Ölmez çiçek bitkisinde uçucu yağ oranı hasat dönemlerine göre (ontogenetik varyabilite) ve bitki kısımlarına göre (morfogenetik varyabilite) değişiklik göstermektedir (Bianchini ve ark., 2001; Paolini ve ark., 2006; Satta ve ark., 1999). Benzer şekilde bitkinin gelişme dönemlerine göre yapılan hasatlardan elde edilen uçucu yağ oranları da değişmiş olup, en yüksek değer çiçeklenme başlangıcı dönemden alınmıştır. Araştırma sonuçları bazı araştırıcıların bulduğu değerlerden (Blažeković ve ark., 1995; Kılıçarslan, 2020; Satta ve ark., 1999) yüksek, bazı araştırıcıların değerleriyle (Bilandžija ve ark., 2022; Göre ve Avcı, 2022; Talić ve ark., 2019) uyumlu, bazı araştırıcıların değerlerinden düşük (Judzentiene ve ark., 2022) çıkmıştır. Melito ve ark. (2016), özellikle tıbbi ve aromatik bitkilerin uçucu yağ bileşimi ve veriminin agroteknik uygulamalardan, ekolojik ve iklim faktörlerinden etkilendiğini bildirmişlerdir.

Çiçek Uçucu Yağ Verimi

H. italicum bitkisinin farklı gelişme dönemlerinde elde edilen uçucu yağ verimine ait varyans analizi sonucunda hasatlar arasında %1 düzeyinde önemli farklılık bulunmuştur. Çiçek uçucu yağ verimleri 0.22-0.4 l/da arasında değişmiştir. (Çizelge 2). En yüksek verim 0.4 l/da tam çiçeklenme döneminde, en düşük verim 0.22 l/da çiçeklenme başlangıcı döneminde elde edilmiştir. Elde ettiğimiz bulgular bazı araştırıcıların bulduğu değerlerden (Čagalj ve ark., 2019; Miloradović, 2018) düşük çıkmıştır. *H.italicum*'da uçucu yağ verimi, kuru çiçek miktarına ve bitkinin içerdiği uçucu yağ oranına bağlı olarak değişiklik göstermektedir. (Pohajda ve ark., 2015).

Çizelge 2. *H. italicum* bitkisinin farklı gelişme dönemlerinde elde edilen uçucu yağ oranı (%) verim (l/da) değerleri

Hasat Zamanları	Çiçek uçucu yağ oranı (%)	Çiçek uçucu yağ verimi (l/da)
Çiçeklenme Başlangıcı	0.88 A	0,22 C
Tam Çiçeklenme	0.44 B	0,40 A
Çiçeklenme Sonrası	0.30 C	0,33 B
EGF (%5)	0.11	0.055
C.V(%)	2.01	7.54

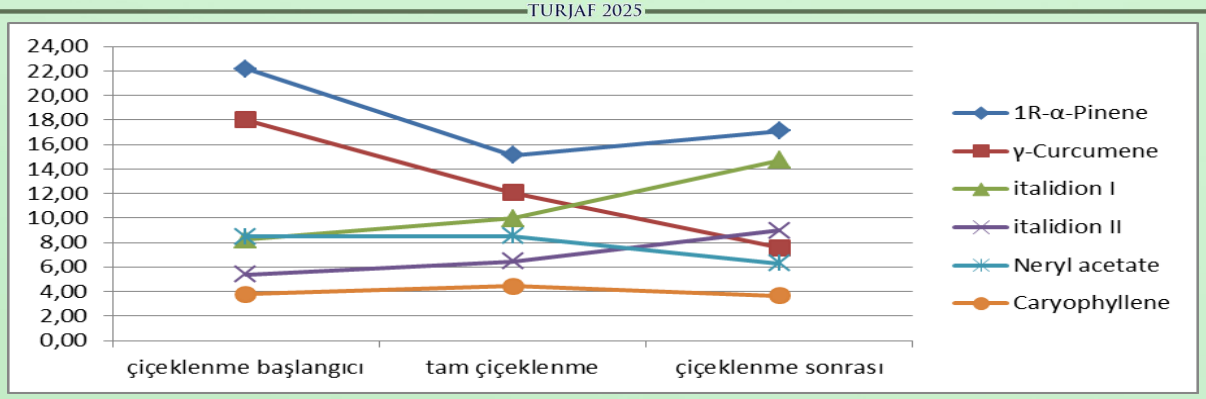
Uçucu Yağ Bileşenleri

H. italicum bitkisinin uçucu yağı fitoterapinin yanı sıra kozmetik, ilaç, tarım, gıda sanayi gibi farklı alanlarda da kullanımına olanak sağlar (Morone-Fortunato ve ark., 2010). *H.italicum* uçucu yağı Avrupa Farmakopesinde yer almamakta ve belirli standartı bulunmamaktadır (Bilandžija ve ark., 2023). Kullanım amacı bitkinin kemotiplerine göre değişiklik göstermektedir, bu yüzden uçucu yağın içeriği büyük önem taşımaktadır. Araştırma sonucunda uçucu yağda 38 bileşen tanımlanmış olup ana bileşenleri, α-pinene (%15.11-22.16), γ-curcumene (%7.57-18.20), italidion I (%8.25-14.72), Neryl acetate (%6.31-8.53), italidion II (%5.38-8.98), caryophyllene (%3.66-4.43) ve β-Selinene (%4.27-5.36) olup, bu bileşenlerin oranlarının bitkinin hasat zamanlarına göre değişiklik göstermiştir (Çizelge 3). Furlan ve Bren, (2023) ölmez çiçek uçucu yağında bulunan bazı bileşenleri benzer şekilde α-pinen, limonen, nerol, neryl asetat ve neril propanoat, α-selinen, β-selinen, γ-curcumen ve eudesm-5-en-11-ol olarak belirlemiştir. Djihane ve ark. (2016), Cezayir'de yaptıkları araştırmada bitkinin uçucu yağının baskın bileşenleri α-cedren %13.61, α-curcumen % 11.41, geranil asetat % 10.05, limonen % 6.07, nerol % 5.04, neryl asetat % 4.91 ve α –pinen % 3.78 olarak belirlemişlerdir.

Uçucu yağ içeriğinin değişimi, damıtılacak bitki kısmına, genotipine, bitki yaşına, coğrafi kökene, toprak tipine, toprak asitliğine, güneşlenme süresine, sıcaklık, nem, iklim, rakım, hasat zamanı ve kurutma yöntemine, yağ çıkarma yöntemi gibi birçok etkene bağlıdır (Ninčević Runjic ve ark.,2025; Bahadırlı ve ark., 2024; Aćimović ve ark., 2022; Furlan ve Bren, 2023; Kunc ve ark., 2022; Melito ve ark., 2016; Ninčević ve ark., 2019; Peršić ve ark., 2019). Çevresel faktörler arasında, toprak tipi ve coğrafi konum, ölmez çiçeğin uçucu yağ bileşimindeki farklılığın ana sebebi olarak görülmektedir (Bianchini ve ark., 2003).

Çizelge 3. *H. İtalicum* bitkisinin farklı gelişme dönemlerinde elde edilen uçucu yağ bileşenleri

Uçucu Yağ Bileşenleri	RT	Çiçeklenme Başlangıcı	Tam Çiçeklenme	Çiçeklenme Sonrası
α-Pinene	9.58	**22.16**	**15,11**	**17,09**
β-Pinene	12.63	0.46	0.28	0.23
D-Limonene	16.50	3.29	3.18	2.20
Eucalyptol	16.97	1.07	0.89	1.59
gamma.-Terpinene	18.61	0.89	0.50	0.51
2-Carene	20.37	0.77	0.50	0.47
Butyl angelate 2-methyl-1-	25.35	0.98	0.73	-
Copaene	30.66	0.70	1.05	1.75
Linalool	31.85	1.60	1.75	1.46
Isoitalicene	32.91	0.69	0.91	1.06
α-Bergamotene	33.77	0.68	0.52	0.31
Terpinen-4-ol	34.51	2.34	1.01	0.99
Caryophyllene	35.15	**3.78**	**4.43**	**3.66**
Elixene	38.35	2.52	2.53	2.22
endo-Borneol	38.57	0.29	0.28	0.41
γ-Curcumene	38.80	**18.20**	**12.06**	**7.57**
Neryl acetate	39.58	**8.50**	**8.53**	**6.31**
β-Cadinene	39.96	0.57	0.33	0.46
β-Selinene	40.23	**4.81**	**5.36**	**4.27**
α-Selinene	40.38	**3.51**	**3.62**	**2.17**
β-Curcumene	40.72	0.34	0.27	0.95
δ-Cadinene	41.53	0.49	0.67	0.90
α-Curcumene	41.87	0.92	1.65	1.85
Neryl propionate	42.13	0.98	1.22	0.65
cis-Geraniol	42.26	0.65	1.21	1.37
italidion I	45.84	**8.25**	**9.96**	**14.72**
italidion II	46.05	**5.38**	**6.45**	**8.98**
9-Undecene-4,6-dione,3,5,7,10-tetramethyl	49.07	1.30	1.82	2.04
Guaiol	53.33		0.65	0.46
Rosifoliol	54.59	0.8	1.93	0.84
Neointermedeol	55.08	0.26	0.44	0.25
tau.-Cadinol	56.06	0.45	0.48	0.55
Copaborneol	56.41	0.75	1.54	-
Thymol/Carvacrol	56.70	0.31	0.50	5.19
alpha.-Bisabolol	57.42	0.27	0.54	0.37
α-Eudesmol	57.82	-	0.40	0.42
β-Eudesmol	58.13	0.27	0.73	0.83
Neointermedeol	58.85	0.77	1.52	0.85
TOPLAM		100.00	97.78	95.95



Şekil 1. *H.italicum* uçucu yağında bulunan ana bileşenlerin hasat zamanlarına göre değişimi

Çalışmamızda *H.italicum*'da farklı gelişme dönemlerinde yapılan hasatlarda uçucu yağın kimyasal profililinin değiştiği, ana bileşenler olan , α-Pinene, γ-Curcumene, italidion I, Neryl acetate, italidion II, Caryophyllene ve β-Selinene oranlarının bitkinin gelişme dönemlerine göre değişim (ontogenetik varyabilite) grafiği (Şekil 1)'de gösterilmiştir. İtalidion I ve II en düşük çiçeklenme başlangıcında yapılan hasatta elde edilirken tam çiçeklenme döneminde artarak çiçeklenme sonrası dönemde en yüksek seviyeye ulaşmıştır. γ Curcumene çiçeklenme başlangıcında yapılan hasatta en yüksek seviyede iken çiçeklenme döneminden itibaren düşerek çiçeklenme sonrası dönemde en düşük seviyede olmuştur. Neryl acetate çiçeklenme başlangıcı ve tam çiçeklenme dönemlerinde benzer oranlarda bulunurken çiçeklenme sonrasında düşüş göstermiştir. α-Pinene çiçeklenmeye başlangıç hasatında en yüksek seviyede bulunurken tam çiçeklenme haşatında düşüş göstermiş fakat çiçeklenme sonrası dönemde tekrar artmıştır.

Verim ve Kalite Bileşenlerinin Korelasyon Analizi

H.italicum bitkisinin verim ve kalite bileşenlerinin korelasyon analizi sonuçları (Şekil 2.) incelendiğinde bitki boyu, taze herba (+0.98), kuru herba (+0.94), taze (+0.92) ve kuru çiçek (+0,98) verimleri arasında pozitif bir korelasyon bulunduğu görülmüştür. Uçucu yağ verimi ile kuru herba ve taze ve kuru çiçek verimi arasında sırasıyla yüksek pozitif korelasyon (+0.90, +0.92, +0.82) bulunmaktadır. Uçucu yağ bileşenleri incelendiğinde ise α-pinen ve γ-curcumene ile çiçek uçucu yağ oranı arasında yüksek pozitif (+0.88, +0.98) korelasyon kuru çiçek verimi arasında yüksek negatif korelasyon (-0.88,-0.98) bulunmuştur. Γ-curcumene ve italidion I arasında yüksek negatif korelasyon (-0,94), neryl acetate ile arasında yüksek pozitif korelasyon (+0,81) bulunmaktadır. Neryl acetate ile italidion I arasında yüksek negatif (-0,96) korelasyon bulunmuştur. Ayrıca uçucu yağ bileşeni italidion I ile bitki boyu, taze herba verimi, kuru herba vermi taze ve kuru çiçek verimleri arasında pozitif bir korelasyon bulunduğu görülmüştür (Şekil 2). Korelasyon analizi sonucu elde dilen veriler araştırma sonuçlarıyla uyum içerindedir.

Sonuçlar ve Tartışma

Çukurova Koşullarında Ölmez Çiçek (Helichyrsum italicum) bitkisinin farklı gelişme dönemlerinde (çiçeklenme başlangıcı, tam çiçeklenme ve çiçeklenme sonrası) verim ve kalite özellikleri (bitki boyu, taze ve kuru herba verimleri, taze ve kuru çiçek verimleri) yanı sıra uçucu yağ oranı ve bileşenlerinin belirlendiği bu çalışmada, kullanılacak amaca göre uçucu yağ içeriği önemli olmakla birlikte, uçucu yağ verim ve kalite özellikleri bakımından H .italicum'da en uygun hasat zamanının çiçeklenme başlangıcı ve tam çiçeklenme dönemi olduğu belirlenmiştir. Bununla birlikte, çiçeklenme başlangıcında da uygun zamanı belirlemek için daha fazla araştırma yapılması gerekmektedir. Çalışma sonucunda ekonomik olarak yüksek değere sahip olan *H.italicum* bitkisinin Akdeniz ikliminin yaşandığı Çukurova bölgesinde yetiştirmeye elverişli olduğu, bununla beraber neryl acetate oranının düşük olması nedeniyle bu değerin artırılmasına yönelik araştırmaların yapılması gerekmektedir.

Teşekkür

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Şekil 2. *H.italicum* bitkisinin verim ve kalite bileşenlerinin korelasyon analizi

BB: bitki boyu, THY:Taze herba verimi, KHY:Kuru herba verimi, KÇY:Kuru çiçek verimi, TÇV:Taze çiçek verimi, ÇUY: Çiçek Uçucu yağ oranı, UYO:Uçucu yağ verimi, UÇYB1:α-Pinene, UÇYB2:γ-Curcumene, UÇYB3:italidion I, UÇYB4:Neryl acetate

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Feather-Plucking in Blue-Breasted Quails (*Synoicus chinensis*): An Abnormal Behavior Associated with Courtship Feeding?

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Abstract

Twenty pairs of blue-breasted quail were utilized in this study. Lettuce was provided daily to the quails beginning at 70 days of age. Observations of feather plucking, feather eating behavior, and feather condition scores were made at 65 and 100 days of age. Furthermore, the number of fertile eggs from the first ten eggs was recorded during the periods of 52-70 days and 95-115 days of age.
This study examines the relationship between feather plucking and courtship feeding in blue-breasted quail. It was hypothesised that the plucking behaviour observed in both males and females may be linked to courtship feeding, with males offering plucked feathers to females. However, statistical analysis revealed no significant correlation between feather condition scores and the number of fertilized eggs at both 52-70 days and 95-115 days ($P > 0.05$). The results suggest that while feather plucking, followed by its consumption by females, may be linked to courtship feeding, it remains unclear whether this behavior directly influences reproductive success in this species, as no significant correlation was found in this study.

Key Words: *blue-breasted quail, feather plucking, courtship feeding, abnormal behavior*

Mavi Göğüslü Bıldırcınlarda (*Synoicus chinensis*) Tüy Yolma: Kur Beslenmesiyle İlişkili Anormal Bir Davranış mı?

Özet

Bu çalışmada yirmi çift mavi göğüslü bıldırcın kullanılmıştır. Bıldırcınlara 70 günlük yaştan itibaren her gün marul verilmiştir. Tüy yolma, tüy yeme davranışı ve tüy kondisyon skorları 65 ve 100 günlük yaşlarda gözlemlenmiştir. Ayrıca, ilk on yumurtadan elde edilen döllü yumurta sayısı 52-70 günlük ve 95-115 günlük yaş dönemlerinde kaydedilmiştir.
Bu çalışma, mavi göğüslü bıldırcınlarda tüy yolma ile kur beslenmesi arasındaki ilişkiyi incelemektedir. Hem erkeklerde hem de dişilerde gözlenen tüy yolma davranışının, erkeklerin dişilere yolunan tüyleri sunmasıyla kur beslenmesiyle bağlantılı olabileceği varsayılmıştır. Bununla birlikte, istatistiksel analiz, tüy kondisyon skorları ile hem 52-70 gün hem de 95-115 gündeki döllenmiş yumurta sayısı arasında anlamlı bir korelasyon olmadığını ortaya koymuştur ($P > 0.05$). Sonuçlar, tüy yolmanın ve ardından dişiler tarafından tüketilmesinin kur beslenmesiyle bağlantılı olabileceğini düşündürse de, bu çalışmada anlamlı bir korelasyon bulunmadığından, bu davranışın bu türde üreme başarısını doğrudan etkileyip etkilemediği belirsizliğini korumaktadır.

Anahtar Kelimeler: *mavi göğüslü bıldırcın, tüy yolma, kur beslenmesi, anormal davranış*

Introduction

Courtship feeding in birds occurs during the breeding season, with males providing food to females over an extended period, starting before egg-laying and continuing through incubation until the eggs reach an optimal temperature for development (Roughgarden, 2013). This behavior is often viewed as a form of paternal investment, where males supply females with nutritional resources that may enhance reproductive success by increasing fecundity. Through courtship feeding, males may also influence the timing of copulation, thereby promoting the production of larger ejaculates, inducing female refractory periods, accelerating oviposition, and ultimately maximizing reproductive success (Albo and Costa, 2010; Albo et al., 2013). On the other hand, while males may attract females by offering food, thereby improving their chances of mating, the production of these gifts is resource- and time-intensive, which can negatively impact male fitness. Females, in turn, can increase their fitness by receiving nutritionally valuable gifts; however, rejecting males without foods may result in missed mating opportunities. Given that the nutritional value of these resources is not fully understood, certain courtship feeding behaviors may enhance male reproductive success without directly benefiting females nutritionally. Consequently, the reproductive interests of both sexes may not always align, leading to sexual conflict where the fitness goals of each sex are in opposition, preventing either from achieving an optimal outcome (Parker, 2006).

The pecking behavior, which consists of targeting the feathers of other birds and sometimes pulling out and consuming them (Blokhuis, 1989), is believed to facilitate digestion, although birds are unable to digest keratin, rendering feathers nutritionally insignificant (McKeegan and Savory, 1999; Mens et al., 2020). Five types of pecking are identified: aggressive pecking, gentle feather pecking without removal of feathers, severe feather pecking leading to feather loss, tissue pecking in denuded areas, and vent pecking (Savory, 1995). Gentle feather pecking and severe feather pecking are abnormal and destructive behaviors, typically seen only in captive birds (Mens et al., 2020). Severe feather pecking, tissue pecking, and vent pecking are considered injurious pecking and can lead to cannibalism. Aggressive pecking, however, is a natural behavior with a clear purpose and is not comparable to the other types. Directed at the head and neck of conspecifics, aggressive pecking is used by birds to establish a stable dominance hierarchy, known as the pecking order (Savory, 1995). Two primary hypotheses have been proposed to explain the occurrence of feather pecking: the lack of ground pecking for foraging behavior (Blokhuis, 1986) and the lack of pecking during dustbathing behavior (Vestergaard and Lisborg, 1993). Both hypotheses suggest that the lack of adequate foraging or dustbathing substrates in the environment may create an obstruction, or that the bird's strong motivation to engage in ground pecking behavior remains unfulfilled. This frustration, resulting from the inability to express motivated behavior, can lead to the redirection of pecking towards alternative targets such as feathers and/or conspecifics. As a direct consequence, frustration may contribute to feather pecking, or indirectly exacerbate stress, which further promotes the behavior (Mens et al., 2020). The currently more widely accepted directed foraging hypothesis posits that feather pecking is not an act of aggression, but rather a form of directed foraging behavior. This may occur when birds misperceive feathers as an appropriate foraging substrate (Riber et al., 2007).

In the ethogram of blue-breasted quail, courtship feeding behavior is identified as tidbitting, a behavior exhibited exclusively by males (Schleidt et al., 1998). Feather plucking in blue-breasted quail is a problem typically observed in overcrowded flocks, whereas it occurs rarely in smaller groups (Landry, 2015).

This study aims to investigate the relationship between feather pecking and courtship feeding in male and female blue-breasted quail in captivity. It hypothesizes that feather pecking in males, followed by courtship feeding (tidbitting), may result from redirected foraging behavior, where males offer food after engaging in feather pecking. The study seeks to provide insights into how feather pecking and courtship feeding behaviors are interconnected and how these interactions may influence reproductive behaviors and maladaptive behaviors in captive conditions.

Materials and Methods

Bird Management and Husbandry

The study was conducted at the Animal Breeding Laboratory of the Faculty of Agriculture, Isparta University of Applied Sciences, in Isparta, Turkey. Fertilized blue-breasted quail (*Synoicus chinensis*) eggs were incubated at 37.5°C with approximately 50% relative humidity for the first fourteen days, followed by incubation at 37.1°C with approximately 60% relative humidity for the final three days. The chicks hatched after 17 days of incubation. The chicks were initially housed in brooders. The brooder temperature was maintained at 41±1 °C, while areas not directly exposed to heat radiation remained at approximately 35 °C during the first two weeks. Thereafter, the temperature was gradually reduced by 2 °C every two days until it reached 20 °C. Chicks were exposed to continuous 24-hour lighting for the first five weeks.

At the end of five weeks of age, the quails were separated by sex and housed in cages (33×40 cm) with six quails per cage. As the laying period began, one male and one female were randomly paired and housed together in the same cages. A total of 20 pairs (20 males and 20 females) of blue-breasted quail were used in this study. The breeding room maintained an ambient temperature ranging from 20 to 25 °C, with a relative humidity of 60–70% and a natural photoperiod of 14 hours of light and 10 hours of darkness (14L:10D) for the remainder of the experiment.

The feed for blu-breasted quails contained 20% crude protein and 2800 kcal of metabolizable energy per kg until four weeks of age, after which it was adjusted to 17% CP and 2750 kcal of ME/kg for the remainder of the study. The cages were equipped with improvised feeders and drinkers, ensuring ad libitum access to water and feed.

Study design and traits

The first 10 eggs laid by the female quails, housed in pairs, between days 52 and 70 were checked for fertility. In addition, feather plucking and feather eating behaviors of both male and female quail pairs were observed between 15:00 and 17:00 at 65 days of age. Furthermore, feather condition scores at the same age were assessed using a scale adapted from Khalil et al. (2015), ranging from 1 (completely feathered) to 5 (featherless), based on observations of the condition of the feathers on the head, neck, and back. Total values for each bird could range from a minimum of 3 (fully feathered) to a maximum of 15 (featherless), calculated by summing the values of the three areas.

After 70 days of age, lettuce was given daily to reduce feather plucking and feather eating behaviors. Similar observations and measurements were repeated for quails at 100 days of age. In addition, fertility checks were performed separately for the first 10 eggs laid at 95 and 115 days of age. A total of 400 eggs were used to determine fertility.

Statistical analysis

The correlation between feather condition scores of male and female and fertile egg number was analysed using Kendall's tau-b, two-tailed test. Statistical analyses were conducted using the SPSS software (version 27.0; IBM Corporation, Armonk, USA).

Results and Discussion

Figure 1 presents the number of quails exhibiting feather plucking and eating behaviour within the twenty pairs, along with the corresponding pair numbers. As depicted in Figure 1, feather plucking behaviour was exhibited by two male individuals at 65 days of age, while at 100 days of age, this behaviour was no longer observed. Similarly, at 65 days of age, two female individuals demonstrated feather plucking behaviour, whereas at 100 days of age, males in the pairs were noted to engage in feather plucking. Feather eating behaviour was exclusively observed in female individuals and occurred after feathers were presented by males. In addition, a 65-day-old female and a 100-day-old female were observed consuming feathers plucked from their mates. In one instance, a female at 65 days of age plucked a large area of feathers from the male's back without consuming them. The feather plucking behaviour observed among females during the early age period may potentially be attributed to stress associated with mate formation and the necessity of feed presentation during mating. At 100 days of age, plucking occurred in one female and one male in separate pairs, and in these pairs the feathers were consumed by the females.

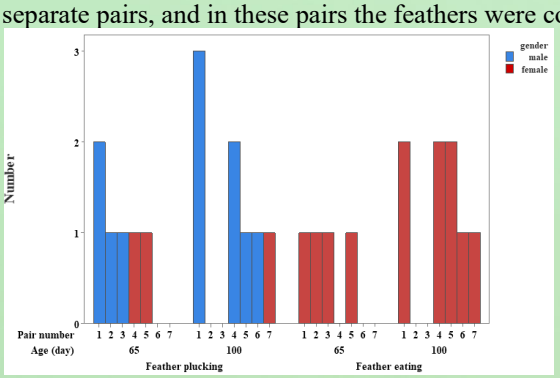


Figure 1. Feather plucking and eating in blue-breasted quail

The results suggest that feather-plucking behavior can develop immediately after pairing. Although this behavior was observed in both males and females, it was noted that the males presented the feathers they plucked to the females as courtship food, which the females subsequently consumed. In other words, the male quail offers the feathers plucked from its mate back to the mate, while the female quail may consume the feathers plucked from the male. On the other hand, Odén et al. (1999) reported that no a male towards a female feather pecking was observed in laying hens. In this study, outside of observation hours, when the female was not interested in the feather offered, the male quail was able to consume the plucked feather.

Hereditary influences, dietary composition, environmental conditions, and husbandry strategies are key determinants in the multifactorial etiology of feather plucking (Schreiter et al., 2020). However in this study, in blue-breasted quail, feather plucking was observed in certain individuals, while absent in others.

The correlation analysis between the feather condition scores of male and female and fertile egg number at 52-70 and 95-115 days is presented in Table 1 and 2, respectively.

Table 1. Correlation coefficients between feather condition scores and fertile egg number at 52-70 days

	Fertile egg number	Male feather score
Male feather score	0.053 (0.792)	
Female feather score	0.185 (0.360)	0.127 (0.522)

The *P*-values are presented in parentheses.

It has long been suggested that hens with increased feather loss on their backs tend to have higher reproductive success compared to those with greater feather coverage (Shi et. al., 2019). Nonetheless, in this research, the Kendall's Tau correlation coefficients, based on data from 20 individuals at 52-70 day, non-significant correlations between the variables: fertile egg number and male feather score ($\tau = 0.053$, $P = 0.792$), fertile egg number and female feather score ($\tau = 0.185$, $P = 0.360$), and male feather score and female feather score ($\tau = 0.127$, $P = 0.522$), suggesting no significant relationships.

Table 2. Correlation coefficients between feather condition scores and fertile egg number at 95-115 days

	Fertile egg number	Male feather score
Male feather score	0.233 (0.250)	
Female feather score	0.168 (0.383)	0.308 (0.110)

The *P*-values are presented in parentheses.

In the previous analysis of individuals aged 52-70 years, no significant correlations were found between the variables (Table 1). Similarly, in the current analysis of individuals aged 95-115 days, there were no significant positive relationships, as indicated by the Kendall's Tau correlation coefficients: fertile egg number and male feather score ($\tau = 0.233$, $P = 0.250$), fertile egg number and female feather score ($\tau = 0.168$, $P = 0.383$), and male and female feather scores ($\tau = 0.308$, $P = 0.110$). Overall, these results suggest that there are no statistically significant associations between the variables.

Feather plucking and/or eating in cage-reared blue-breasted quail may have been motivated by courtship feeding as well as misperception of feathers as a suitable foraging ground. On the other hand, the correlations between the feather condition score and the number of fertilised eggs were not statistically significant. However, it is particularly noteworthy in this species that some male quail present plucked feathers to females in a manner resembling courtship feeding.

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Economics of Agriculture and Sustainability of Agro-Economy

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Abstract

Agricultural finance is an important and complex structure involving actors such as suppliers, farmers, food processors, logistics, wholesalers, retailers and governments in the agricultural food supply chain. Efforts to increase the unit area yield and quality of field crops that have strategic importance in human life are a matter of curiosity for the scientific community. At this point, food safety and food security emerge as the most important issues in addition to the field crops as well. Agri-food supply chain management is a philosophy that envisages supply chain members working as a single business in order to increase efficiency and added value in the journey of food products from farm to fork. In order to combat all these challenges and ensure that people have access to quality food at adequate and reasonable prices, the proper management of the agricultural-food supply chain with the participation and contribution of all actors, from farmers to consumers, from businesses to states, will be among the most important issues in the future, as it is today. Although the subject of the agri-food supply chain is plant and animal products, only the field crops aspect is discussed in this study because the subjects are very broad. This study was prepared in the light of science to address the problems in this regard, to reveal the developments, and to examine the situation of the sector over the world.

Key Words: *Agricultural economy, Agricultural policy, Business administration, Strategic crops*

Introduction

The survival of human beings and the continuity of healthy generations depend on meeting nutritional needs under the right conditions. At this point, food safety and food security are the most important issues. Nutrition directly affects daily activities by taking and using the nutrients required for human beings to be productive and productive in order to continue their lives. The agricultural-food supply chain must be managed in a way that is appropriate for the purpose in order for people to have access to quality and sufficient food. Economic growth, the factors that trigger growth, the components of growth and the limits of growth are the oldest and most important topics in economic literature. The agricultural sector shows itself at multiple points in almost every field related to humans on earth. At the same time, it has a semantic integrity that develops a relational network within extremely complex, different socio-economic activities and application areas.

Recent studies have focused on the impact of CO_2 emissions in order to achieve sustainable development, reduce global warming, improve environmental quality and develop necessary measures and policies (Stern, 2011). Developed and developing countries were compared (Tiffin and Irz, 2006) and concluded that agriculture is a driving force for growth in developing countries. When the competitiveness of developed countries is ignored, the impact of the agricultural sector on growth is limited. Since agricultural and food products are perishable products, they require more sensitivity than other products in processing, packaging, wrapping, storing, shipping, offering for sale, in short, delivering them to the consumer (Manzini and Accorsi, 2013). About 58.97% of the total agricultural and food products transported in the world (ton*km) were transported by sea and 40.87% by road. Only 0.16% were transported by air (Poore and Nemeccek, 2018).

The state has expectations from agricultural entrepreneurs such as complying with the rules and paying taxes, and sustainability in transferring a livable world to future generations (Ministry of Development, 2018). Today, the concepts of sustainability of development besides sustainability have gone far beyond for field of natural based resources including forestry management and also have entered to the discourses and practices as well in urban based development, tourism, politics, education, agriculture, manufacturing, logistics and all other areas of trade (Heinrichs et al., 2016). Issues such as food supply fear, pollution, and animal welfare are becoming important in consumer attitudes in order to evaluate past events and predict future behaviors in line with research in food and agricultural marketing (Walley et al., 2016). This study was prepared in the light of science to address the problems in this regard and to reveal the developments.

Economics of Agriculture and Sustainability of Agro-Economy

Agricultural activities and farming of plants is kind of science which focused on plant and animal production, the preservation of these products under appropriate conditions, their processing and evaluation, and their distribution.

Food or food is non-drug substances that living beings must consume in order to continue their lives. Growth in sectors other than the agricultural sector creates an increase in the wages of agricultural sector employees (Estudillo and Otsuka, 1999). An entrepreneur is an innovative person who takes precautions against competition and develops himself and his business and manages the business successfully (Manimala and Thomas, 2017). All stages in the marketing channel of agricultural products create a food value while creating shape, time, place, and property benefits (Norwood et al., 2021).

The increase in net output in the agricultural sector will cause an increase in the amount of product in the country. This increase will primarily affect net total growth, and secondly, an increase in per capita production will be provided (Kuznets, 1961). There is a risk at every stage of the agricultural-food supply chain. This risk is relevant both in terms of food safety and losses. Agricultural marketing activities, which consist of many interrelated activities likewise planning of production, raising and harvest, trashing, classification, packaging, transportation, warehouse-silo-storage, agricultural and food based processing, organizing and allocation, advertisiment and sales, are among the issues that concern agricultural producers in terms of decisions regarding which product will be grown, when it will be harvested, in which markets it will be offered for sale and its storage (Vadivelu and Kiran, 2013). Marketing is the correct identification and meeting of consumers' demands and needs in order for the business to achieve its goals (Ritson, 1986). In a world that is becoming more interconnected, people at every level of marketing systems have to act together to implement marketing strategies and plans (Armstrong et al., 2014). The supply chain is defined as a network of organizations that come together through upstream and downstream connections that create value for the end consumer as a product or service as a result of different processes and activities (Christopher, 1992). When an example is examined on the subject, it is seen that exports exceeded imports in the 2017-2018 period when India's agricultural product imports and exports were examined as a result of the implemented policies. However, it is seen that India experienced fluctuations in the production of agricultural products due to problems in irrigation infrastructure and structural deficiencies (Sheeba and Reena, 2019). Researchers examined the effects of R&D expenditures made through domestic and foreign channels on agricultural productivity in 30 Sub-Saharan African countries between 1981-2011 years. Their studies indicate that knowledge accumulation and investments made in this field are very important (Adetutu and Ajayi, 2020).

For a comprehensive perspective, life cycle analyses have come to the forefront and all stages of production processes from input production to waste generation should be analyzed (Smith, 2008). Production process losses due to adverse climatic conditions, product losses remaining in the field due to inadequate prices, and losses resulting from products not accepted for export are also in question. Economic reforms such as the removal or reduction of regulatory institutions in the agricultural sector, the reduction of the role of the public in issues such as subsidized credit, etc. for agriculture, and the regulation of regional and seasonal product pricing strategies have major impacts on agricultural markets (Kindness and Gordon, 2001). It is also observed that the use of new technologies in the agricultural supply chain is increasing. The Internet of Things, block chain, and big data technologies are seen as potential providers of a sustainable agriculture-food supply chain (Kamble et al., 2019). For example, China, which largely meets its needs on a product basis, is an important country in the world agricultural sector as both a producer and a consumer with its high population (FAO, 2020).

An agricultural entrepreneur is someone who starts a business with an entrepreneurial spirit in small-scale farming or who uses managerial skills to grow their business (Morgan et al., 2010). Sustainability of supply chain and its management has been emerged as a type of growing issue that is progressively gaining attention in its field (Seuring and Müller, 2008). Approximately 1/3 ratio of products in agricultural-food supply chains are wasted throughout the chain. Almost by 40% ratio of the lost by underdeveloped besides developing defined countries formed in logistics based processes (storage, transportation and packaging), while 40% of the losses in developed countries occur in retail and consumption processes (Girotto et al. 2015). It is stated that environmental degradation may increase in the early stages of economic growth in a country, but that economic growth will lead to lower levels of environmental degradation in later stages (Rothman, 1998). Managing sustainability in global supply chains continues to be a challenging task. Because sustainability scandals are still repeated for companies with global supply chains (Koberg and Longoni, 2019). On the other hand, the transition from traditional methods to chemical methods in the fertilization system in the agricultural sector leads to serious environmental damage. On the other hand, green technology and eco-innovation reduce the negative effects of pollution by creating new products/services and business methods (Boleti et al., 2021). The transportation of agri-food products must be carried out from a quality, safety and sustainability perspective (Akkerman et al., 2010). The EKC (Environmental Kuznets Curve) hypothesis concluded that there is a kind of inverted U-shaped relations among the country's economic growing and greenhouse gas emissions (Grossman and Krueger, 1991). On the other hand, Cooperatives are organizations operating in the entire agricultural value chain, from the cultivation of agricultural products to animal husbandry, and the industrial processing of agricultural products and animals (Lerman and Parliament, 1991).

Sustainable development requires the use of natural and human resources for the future and at the lowest possible consumption rate, considering the needs of future generations (Keating, 2003). Concerns about the difficulty of energy supply to meet demand, combined with concerns about global warming and nature, lead to continued

interest in researching the relationship between variables related to energy, economic growth and environmental damage (Chandran and Tang, 2013). In order to ensure the continuity of development and to guarantee human life, the continuity of resources should also be ensured (Harrison, 1993). Since the size of the agricultural sector means that the factors affecting agriculture have great effects, the impact of macroeconomic variables and the concept of agricultural productivity on each other is considered reasonable (Gollin, 2010).

The main objectives of agricultural entrepreneurs are to sustain their existence and grow their agricultural enterprises by producing/marketing agricultural products to make a profit (Dias et al., 2019). The verifiability of traceability, which is seen as an important criterion in food quality and food safety, is increasingly demanded by consumers in different parts of the world (Opara, 2003). Population growth, combined with current unsustainable and wasteful food consumption and production patterns, further exacerbates environmental threats, putting more pressure on climate change, natural resources and the environment (Rohmer et al., 2019). Although the world aims to reduce the impact of climate change, bringing about tangible change requires significant resources and funds in most developing countries (Levinson and Taylor, 2008).

Economic growth is important among policy makers because it is one of the basic macroeconomic indicators. In this context, the EKC hypothesis, the link between economic growth and environmental degradation, is a highly controversial issue. While many studies support the EKC hypothesis (Grossman and Krueger, 1991; Pata, 2018; Malik et al., 2020), some studies did not find the hypothesis valid within the scope of the examined country or country groups (Bartlett, 1994; Apergis, 2016; Adu and Denkyirah, 2019). The raw materials of food products are generally agricultural products, and agricultural products are largely composed of field crops and are also called unprocessed food products. In the production of agricultural products, seeds, seedlings, fertilizers, pesticides, water, agricultural machinery and equipment are required. Inflation in agricultural product prices directly affects food product prices. A decrease in inflation in consumer prices can be achieved with strong cooperatives, effective planning and control, efficient marketing and logistics. We are experiencing a period in which agricultural business management and entrepreneurial spirit come to the fore, according to the knowledge and skills needed to produce according to changing customer demands and new technologies.

Conclusions

The production structure in the global economy is undergoing a rapid transformation. The complexity of agricultural production and financial relations is increasing due to the impact of globalization, and significant challenges are being faced due to factors such as climate change and the Covid-19 pandemic. In order to combat all these challenges and ensure that people have access to quality food at adequate and reasonable prices, the correct management of the agricultural-food supply chain with the participation and contribution of all actors, from farmers to consumers, from businesses to states, will be among the most important issues in the future, as it is today. The increase in consumer prices for agricultural products is far beyond producer prices. In other words, while the producer sells the product cheaply, the consumer continues to consume the same product expensively.

While the contribution of the agricultural sector to the national income of countries is below 10% in most countries, it is of great importance with the healthy nutrition of the population, the place of agriculture in foreign trade, the employment it provides, and other effects (energy, food, supportive medicine, cosmetics). The fact that the agricultural sector provides input for many branches of industry, the gradual decrease of scarce resources, changes in consumer behavior, increasing costs, environmental protection and the increasing importance of human health cause the interest in agricultural marketing practices to increase even more. While the level of customer service increases with technological developments, it is of great importance to ensure operational excellence by carrying out supply chain processes faster, more accurately and efficiently, and to conduct multidisciplinary research based on sustainability.

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Sinkholes and Agricultural Sustainability

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Abstract

Natural disasters are known as natural events that suddenly occur in a certain region on earth, create social stress, create significant losses on people and human settlements, and disrupt life in society. Sinkholes are considered a natural disaster that can cause serious damage to society and the environment. Such unpredictable geological disasters have the potential to cause irreversible damage, especially to settlements and agricultural areas. There are thousands of sinkholes in regions containing salt, gypsum and carbonate rocks in different parts of the world and the main factor that accelerates them is human activities. Disaster prevention and damage reduction policies can be developed with sinkhole risk assessment studies, and disaster-oriented planning can be made to reduce the damage caused by sinkholes. These natural events that occur beyond human control cause loss of life and property. Within the scope of this study, sinkholes, that are considered as an important component of natural disasters and whose numbers are increasing over the world, and agricultural sustainability are discussed.

Key Words: *Climate Change, Disaster management, Groundwater, Sinkhole susceptibility, Unconscious Agriculture*

Introduction

In general, a sinkhole can be defined as the collapse of underground cavities formed as a result of groundwater interacting with the soil, unable to carry the surface weight. Disasters are events that can occur due to natural or anthropogenic causes, affect people physically, socially or economically, stop or interrupt daily life, and cannot be dealt with by local means (AFAD, 2014). Sinkholes, which are karst landforms, are formed when rocks that can dissolve underground such as limestone (limestone, marl, gypsum, etc.) create cavities over time and the ceilings of these cavities collapse (Tapur and Bozyiğit, 2013). Karstification, unlike the external factors that form the surface (streams, glaciers, volcanoes, wind, coastal geomorphologies), develops similar to a large structure connected to each other both on the surface and underground (Anonymous, 2021). Sinkholes are expressed as "karst collapse areas" in another source (MTA, 2018). The main criteria in the formation of sinkholes are; While natural events such as geological, hydrogeological, tectonic and climatological occur, the main accelerating factor is human activities (Günay et al., 2010; Caló et al., 2017).

There are thousands of sinkholes with similar characteristics in regions containing salt, gypsum and carbonate rocks in different parts of the world. Carbonate rocks cover approximately 13.2% of the world's surface except for Antarctica and Greenland. When evaporitic rocks are included, more than 15% of the world's surface is covered with soluble rocks (Anonymous, 2018). In regions where carbonate rocks such as limestone, clayey limestone, marl, dolomitic limestone, dolomite, and evaporites such as gypsum and anhydrite are widespread in the event of interaction with water, the formation of karstic forms such as caves, dolines, lapias and sinkholes is a common geological and geomorphological event (Erol, 1990; Karadoğan, 2001). Since sinkholes are depressions caused by the dissolution of rocks generally composed from calcium carbonates likewise dolomite and also limestone on the surface, karstic rock areas are even more vulnerable than in other regions (Taheri et al., 2021). The widest mechanisms of crack formation are the unconsolidated alluvial basins, as the groundwater level drops, thinner shaped alluvium that is close to edge of basin experiences less compression and subsidence than the thicker shaped alluvium close to deeper, basin central part, besides stress resulting from discriminatory compression causes cracks to form in the overlying cover (Anderson, 1988).

That is a well known fact that formation of the sinkholes accelerates with the rapid decrease in groundwater as a result of excessive water withdrawal from wells (Subramani et al., 1983; Galloway et al., 1999; Yılmaz, 2010). In order to prevent unsustainable water use, it is important to modernize irrigation systems and correctly assess water system requirements. Minimizing problems such as over-irrigation and water insufficiency by ensuring that water is delivered to plants in the right amount and time by modernizing irrigation systems, and adopting conscious and sustainable practices in soil protection and management are important steps to reduce the formation of sinkholes (Ewaid et al., 2019; FAO, 2019). In this study, literature information on sinkholes was reviewed, cause-effect relationships were examined and recommendations were made.

Sinkholes and Agricultural Sustainability

Sinkholes are shaped owing to effects by natural hydrogeological, geological, structural geological in addition to geomorphologic situations. Sinkholes are defined as natural wells represented in karst lands (Bui et al., 2018). Karst formations refer to a land formed by dissolution of main rock besides the improvement of underground shaped drainage. For this reason, although they are primarily associated with limestone, they can also form on the other soluble rocks and carbonates (Waltham et al., 2005). In his technical study on sinkholes (Gutierrez, 2016), he generally justifies the implementation of preventive or compensatory risk reduction measures against these formations in economic and/or social contexts. By natural types geologic factors which give rise to formation for the sinkholes, lithological characteristics and geologic structure, climatic changes, drought factors, hydro-geologic characteristics cannot be controlled by humans, but one of the most important factors that can be controlled is water use (Göçmez et al., 2022). Sinkholes are quite common in all countries in Europe except Iceland, in the Mediterranean and oceanic countries of Africa, in Turkey, Lebanon, Palestine, Israel, Syria, Iraq and Iran in the Middle East, and in Afghanistan, Pakistan, India and China in Asia (Anonymous, 2024a; b). When the literature on sinkholes is examined, it is seen that the subject is more important at the geological and engineering levels, but the sociological importance of the situation is not evaluated in the context of climate crisis, drought and unconscious agricultural practices (Saa, 2022).

It is important to implement preventive planning and corrective measures in high priority risk areas. Anthropogenic factors such as land use, excessive groundwater use, well density, intensive agricultural activities, etc. increase the frequency of sinkhole formation in many places in the world (Galve et al., 2009; Ke, 2017; Wu, 2018). In this study, the researcher stated three main issues that need to be changed by the laws. The mentioned laws are; re-definition for sinkholes, definition for structure based damages and improvement of quality for the underground research (Zisman, 2013). Sinkhole formations can destroy buildings, roads or railways, causing these structures to collapse and high material losses (Xua et al., 2017). As another result that is revealed by the study (Ciantia, 2023), the disintegration in the ground could trigger collapse over time. It was also stated that following the displacement over time in rocks with this type of disintegration is a method that should be used to calculate the safety life of the structure.

It is expected that sinkholes might be occurred in future welded by same or similar conditions as they occurred in the past, and sinkhole inventory maps are used as a basis in defining the hazard areas and creating hazard maps according to this principle (Orhan et al., 2020). In their research (Sahu et al., 2015), they investigated the collapses that occur in the ground and their causes. They stated that collapses are usually caused by underground mines or sinkholes. They stated the factors affecting the collapse as the working techniques performed in underground mining, adjacent working areas, depth of the work, presence of geological deformations, stresses in the ground, surface topography, decreases in groundwater, precipitation and earthquakes. Since the sinkholes formed in the regions where soluble rocks are located have a continuously collapsing structure, the collapses might be monitored based on the surface. Due to suddenly collapses are not expected by those sinkholes, it is possible to develop monitoring and early warning systems for the people living on them and take precautions against the dangers. The inability to fully detect underground structures such as artificial and natural cavities, groundwater or natural caves causes sudden formation of sinkholes of different sizes and shapes and thus increases the extent of environmental damage (Gutiérrez et al., 2014; 2016). Researchers (Nam and Kim, 2017) stated that they are generally studied from a geological perspective, but engineering solutions for sinkholes are still insufficient, and large collapse sinkholes that may occur in metropolises and cities will pose a very serious threat. Considering the difficulties and dangers related to sinkholes, researchers stated that there is still a lack of geotechnical understanding and methods related to sinkholes and that they are insufficient to measure cost-effective repair methods and technologies for sinkholes.

In the literature, studies on the creation of susceptibility maps for many disasters such as landslides, floods, avalanches, fires have been successfully applied (Malczewski, 2006; Abedi et al., 2021; Iban and A. Sekertekin, 2022; Varol, 2022). Subsurface-based soil erosion throughout a crack trace acts the role for opening, widening besides subsequently development of crack channels (Carpenter and Bradley, 1986). Researchers (Gutiérrez et al., 2009) emphasized that conducting trench-opening examinations in settlements against sinkhole risks is cheaper, more reliable and important in reaching detailed information. In their study (Caudron et al., 2006), they analyzed how the soil and structure interactions will be during of the sinkhole event by quite small-scaled model using a 2-dimensionals ground with the building model. In their study, the researchers stated that considering the ground-structure interactions during the presence of a sinkhole or similar hazard can be very cost-effective. In particular, the effect of human activities on the formation of sinkholes is considerable. The dissolution of calcareous rocks by underground water leads to the formation of sinkholes (Shalev et al., 2006). In their study (Zisman et al., 2009), they investigated the damages in structures caused by sinkholes. They stated that in order to determine the source of the cracks that occur, it is necessary to examine the displacement along the cracks, the geometry and movement of the building.

Financial based costs for deal with conclusions for sinkholes are quite often (Kuniansky et al., 2015). One of the most important points for risk evaluation and management of disasters such as sinkholes is the creation from susceptible maps which predicts besides presenting the spatial probability for the future based disaster (Pradhan et al., 2011; Elmahdy et al., 2020). As reported in a study (Fritz, 1961), disasters provide an opportunity for the restoration of social order, and this reconstruction process can increase community solidarity and mutual assistance. Accurate estimation of crop water requirements is important in agricultural irrigation management to prevent water wastage and to increase agricultural productivity. Accurate estimation of water volumes to be supplied to irrigated areas has the potential to decreasing of risk on water scarcity as well as to guarantee the sustainable usage of the water resources (Todorovic, 2005).

Conclusions

Sinkholes, which are considered as one of the important disaster types, cause seriously security-related affairs in the sites where they appeared. Today, the problems about question are seen on the areas where the basic components likewise a gradual reduce in underground water resource, intensively agriculture based activities carried out devoid of considering climate based features, and the existing geological structures in the regions at risk are risky for the formation of sinkholes. Sinkholes are structures that are considered aspect of nature based disasters and their numbers have been increasing in recent years around the world.

Sinkholes are considered a natural disaster that can cause serious damage to society and the environment. People not using the right methods when using nature and not giving enough importance to sustainability issues can cause natural disasters and have negative social consequences. In addition to human activities, climate and geological events are other factors that affect karst formation. It is of critical importance to educate and raise awareness of people living in places with sinkhole risk and those engaged in agricultural activities, to conduct studies through cooperation, to monitor underground water resources and manage them consciously, and to ensure that natural resources are used in accordance with sustainability principles.

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Machine Learning Techniques to Enhance Management and Decision-Making in Commercial Banana Plantations (*Musa* AAA) in Ecuador

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Abstract

This research aims to optimize management and decision-making in commercial banana plantations (*Musa* AAA) in Ecuador through the use of advanced machine learning techniques, with a particular emphasis on identifying and grouping lots affected by Moko, a disease caused by *Ralstonia solanacearum race 2*. The initial component of the study involves analyzing the health status of the plantations using high-resolution images obtained by drones and extracting the Normalized Difference Vegetation Index (NDVI), thereby detecting anomalies associated with Moko outbreaks. This information has been crucial for applying clustering techniques, such as K-means, where specific metrics were used to segment lots according to the intensity of the infection, facilitating the identification of those with the highest concentration of outbreak sites. Additionally, other clustering algorithms, including DBSCAN and hierarchical methods, have been implemented to classify the lots based on post-harvest bunch quality. This segmentation has proven fundamental for decision-making, as it differentiates between high- and low-quality lots, thus optimizing the value chain and logistics in product commercialization. The methodological approach further extends to the analysis of nutritional data, where clustering models have been employed to identify lots with similar nutritional profiles. This information enables the development of highly precise fertilization plans, ensuring greater efficiency in the application of inputs and resource optimization. Furthermore, predictive tools such as linear regression have been explored, driven by the limited number of observations in certain scenarios. At the same time, other predictive algorithms—logistic regression, decision trees, k-nearest neighbors, random forests, and neural networks—are being tested on various datasets from other banana plantations. This comprehensive set of techniques and models significantly contributes to the improvement of agricultural management, enabling early and precise interventions that translate into increased productivity and sustainability in banana cultivation.

Keywords: *Machine Learning, NDVI, Clustering, Postharvest Quality, Agricultural Management.*

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Sustainable Agriculture: Soil and Cover Crops

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Abstract

The products produced in agricultural lands and the production methods used show diversity specific to each region. Many parameters such as social structure, climate, soil structure, water availability in rural areas cause the diversity of products and production methods. It is important to conduct studies on recognizing, protecting and improving soil, which is the most important ecosystem that provides the cycle of life. In order to continue our civilization, we need to switch to more sustainable production methods and give importance to the protection and improvement of species and habitats. In addition to the vegetation in the soil, many different vital activities ensure the continuity of the soil. Additionally, the soil provides sustainability to living life by transforming many substances that may be harmful to the lives of living things. Cover crops are plants grown to increase soil fertility, prevent soil erosion, enrich and protect soil, increase nutrient and water availability and soil quality. Cover crops contribute to sustainability by providing multifaceted benefits to soils used for agricultural production. Evaluation of the condition of the soils, identification of problems in agricultural soils, understanding the importance of protecting the soils, introduction of soil protection and improvement methods used in agriculture, theoretical and practical information on cover crops and soil improvement have been compiled in this study.

Key Words: *Agricultural sustainability, Soil fertility, Soil management, Soil protection*

Sürdürülebilir Tarım: Toprak ve Örtü Bitkileri

Özet

Tarım arazilerinde üretilen ürünler ve kullanılan üretim yöntemleri her bölgeye özgü çeşitlilik göstermektedir. Sosyal yapı, iklim, toprak yapısı, kırsal alanlardaki su bulunabilirliği gibi birçok parametre ürün ve üretim yöntemlerinin çeşitliliğine neden olmaktadır. Yaşam döngüsünü sağlayan en önemli ekosistem olan toprağın tanınması, korunması ve iyileştirilmesi konusunda çalışmalar yapılması önem taşımaktadır. Medeniyetimizi devam ettirebilmek için daha sürdürülebilir üretim yöntemlerine geçilmeli, türlerin ve yaşam alanlarının korunmasına ve iyileştirilmesine önem vermeliyiz. Topraktaki bitki örtüsünün yanı sıra birçok farklı yaşamsal aktivite toprağın devamlılığını sağlamaktadır. Ayrıca toprak, canlıların yaşamına zararlı olabilecek birçok maddeyi dönüştürerek canlı yaşamına sürdürülebilirlik sağlamaktadır. Örtü bitkileri, toprak verimliliğini artırmak, toprak erozyonunu önlemek, toprağı zenginleştirmek ve korumak, besin ve su bulunabilirliğini ve toprak kalitesini artırmak için yetiştirilen bitkilerdir. Örtü bitkileri, tarımsal üretimde kullanılan topraklara çok yönlü faydalar sağlayarak sürdürülebilirliğe katkıda bulunur. Bu çalışmada, toprakların durumunun değerlendirilmesi, tarım topraklarındaki sorunların belirlenmesi, toprakların korunmasının öneminin anlaşılması, tarımda kullanılan toprak koruma ve iyileştirme yöntemlerinin tanıtılması, örtü bitkileri ve toprak iyileştirme konusunda teorik ve pratik bilgiler derlenmiştir.

Anahtar Kelimeler: *Tarımsal sürdürülebilirlik, Toprak verimliliği, Toprak yönetimi, Toprak koruma*

Giriş

Tarımsal faaliyetlerin şekillenmesinde birden fazla faktör rol oynar ve bu faktörler üretim yöntemlerinin verimliliği, sürdürülebilirliği ve çevresel etkilerini belirler. İklim koşulları ve coğrafi faktörler, tarımsal üretim yöntemlerinin çeşitliliğinde büyük bir rol oynar. İklimsel değişkenler (sıcaklık, yağış rejimi ve rüzgar) tarımsal ürün çeşitlerini ve tarımsal üretim yöntemlerinde etkilidir. Toprak özellikleri de tarımsal üretimi etkileyen faktörlerdendir. Toprak yapısı, organik madde gibi unsurlar, üretim sistemlerinin uygulanabilirliğini belirler (Gómez et al., 2018a). Tarım arazilerinin kullanım şeklini topoğrafik yapı, eğim ve rakım gibi unsurlar etkilerken, tarımın yoğunluğu ve üretim teknikleri üzerinde su kaynaklarının varlığı ve sulama olanakları, belirleyici etkiye sahiptir (Schnitkey et al., 2023). Toprak tuzluluğu, asidik ya da bazik yapı gibi faktörler, farklı toprak işleme ve gübreleme yöntemlerinin kullanılmasını gerektirir. Tarımsal üretim yöntemlerini, sosyal ve ekonomik faktörler de biçimlendirir. Çiftçilerin eğitim seviyesi, tarımsal üretim yöntemlerini etkilerken, tarımsal girdi maliyetleri de tarım işletmelerinin üretim kararlarını etkiler. Yerel ve uluslararası pazar talepleri, üretim desenini ve tarımsal

ürün çeşitliliğini etkileyerek, üreticilerin tercih ettiği yöntemlerde farklılıklara yol açabilir (Topçu et al., 2022). Uzaktan algılama teknolojileri, sensörler ve veri analiz sistemleri, hassas tarım tekniklerini teşvik ederek üretim süreçlerini düzenler (Cárceles Rodríguez et al., 2022). Teknolojik yenilikler ve mekanizasyon, tarımsal üretim aşamalarında önemli bir yenilik oluşturmuştur. Modern tarım makineleri, iş gücünü hafifleterek üretim aşamalarını hızlandırır ve verimi yükseltir. Organik ve sürdürülebilir tarım yöntemlerinin ilerlemesi, kimyasal gübre ve pestisit kullanımına yenilikçi çözümler sunarak çevreye hassas üretim yöntemlerine teşvik etmektedir. Tarımsal üretim sistemleri ve teknikleri de büyük bir çeşitliliğe sahiptir (Aparecida et al., 2018). Geleneksel tarım yöntemleri, endüstriyel tarım uygulamaları, organik tarım, sera tarımı, dikey tarım ve hidroponik gibi alternatif üretim yöntemleri, farklı etkilere bağlı olarak kullanılmaktadır. Monokültür ve polikültür sistemleri, üretim sürdürülebilirliği bakımından karşılaştırmalı olarak değerlendirilmekte ve üreticiler tarafından çeşitli şekillerde uygulanmaktadır (Akhzari and Pessarakli, 2016). Tarımsal üretimde sürdürülebilirlik ve çevresel etkiler de önemli bir konudur. Kimyasal gübreler, pestisitlerin çevreye olumsuz etkileri dikkate alındığında, sürdürülebilir tarım sistemleri ile doğal kaynakların korunması ve üretimde verimliliğin artışı oldukça önem arz etmektedir. Tüm bu unsurlar, tarımsal üretimde izlenecek yolun belirlenmesinde ve uygulanmasında rol alır. Bölgesel koşullara uyumlu üretim stratejileri oluşturularak tarımsal verimliliği yükseltmek ve sürdürülebilirliği sağlamak olasıdır.

Sürdürülebilir tarım, doğal kaynakları muhafaza ederek, çevresel etkileri minimize ederek ve gelecek nesillerin taleplerini önemseyip üretim yapmayı hedefleyen bir sistemdir. Geleneksel ve endüstriyel tarım sistemlerinin toprak, su ve biyolojik çeşitlilik için olumsuzlukları bilinmektedir (Gómez et al., 2018a). Gereğinden fazla kimyasal gübre ve pestisit kullanımı, monokültür tarım yöntemleri, fazla toprak işleme ve bilinçsiz su kullanımı gibi faktörler, ekosistem dengesini tehdit ederek toprak erozyonu, tuzlanma, su kaynaklarının eksikliği ve biyolojik çeşitliliğin azalması gibi sorunlara neden olmaktadır (Muhammad et al., 2021). Bu sebeple, sürdürülebilir tarım uygulamalarına geçilmesi kaçınılmaz olmuştur. Toprak, canlı organizmaların yaşamı için zararlı olabilecek çoğu maddeyi dönüştürmek suretiyle canlıların yaşamı konusunda çok yönlü sürdürülebilirlik temelli katkılar sağlamaktadır. Bu makalede sürdürülebilir tarım ve örtü bitkilerinin önemi konusunda yapılmış bilimsel araştırmalar derlenmiştir.

Sürdürülebilir Tarım: Toprak ve Örtü Bitkileri

Sürdürülebilir tarımın öncelikli amaçlarından biri, toprak sağlığını muhafaza etmek ve iyileştirmektir. Toprak organik madde miktarının artırılması, biyolojik çeşitliliğin artırılması ve erozyonun engellenmesi, verimli ve uzun soluklu bir üretim sisteminin temelini oluşturmaktadır (Scavo et al., 2022). Örtü bitkilerinin kullanımı, minimum toprak işleme, doğal gübreleme yöntemleri ve dönüşümlü ekim sistemleri gibi teknikler, toprağın verimliliğini desteklerken çevresel zararları en aza indirger.

Sürdürülebilir tarımın önemli bir bileşeni de su kaynaklarının verimli kullanımıdır (Meyer et al., 2019). Fazla sulama ve hatalı su yönetimi, su kıtlığına ve toprak tuzluluğuna sebebiyet verebilir. Damla sulama, yağmurlama sulama gibi gelişmiş sulama yöntemlerinin uygulanması, suyun etkili kullanılmasını mümkün kılarak hem verimi artırır hem de çevresel sürdürülebilirliğe destek olur.

Kimyasal bağımlılığı azaltarak biyolojik çeşitliliği teşvik etmek de sürdürülebilir tarımın bir diğer önemli yönüdür. Bununla birlikte, genetik çeşitliliğin muhafazası ve yerel çeşitlerin kullanımının desteklenmesi, tarım sistemlerinin farklı çevresel şartlara uyum sağlamasında etkili olur (Fayiah et al., 2019).

Sürdürülebilir tarım tekniklerinin uygulanması, sadece çevresel yararlar oluşturmakla kalmaz, bunun yanında çiftçilerin ekonomik durumunu da artırabilir. Uzun süreli toprak verimliliğinin muhafazası, girdi maliyetlerinin düşmesi ve doğal kaynakların daha verimli kullanımı, üreticilere ekonomik destek sağlar. Tüketiciler ise, sağlıklı ve besleyici değeri yüksek ürünlere erişerek sürdürülebilir gıda ürünlerinden faydalanır.

Böylece sürdürülebilir tarımsal teknikler, doğal kaynakların muhafazası, çevresel zararın azaltılması, ekonomik sürdürülebilirlik ve gıda güvenliğinin geliştirilmesi yönünden elzemdir. Bu sebeple, tarımsal üretimde çevre dostu uygulamaların artırılması ve sürdürülebilirlik temelli politikaların oluşturulması gerekmektedir.

Ekosistemin temel bileşenlerinden biri olan toprak, canlı yaşamı için hayati bir kaynaktır. Bitkilerin büyümesi ve gelişmesi için besin maddeleri sağlar, su döngüsünde yer alır ve mikroorganizmalar için yaşam ortamı oluşturur. Birçok ekolojik süreçte (tarımsal üretim, orman ekosistemleri, doğal döngülerin devamlılığı, iklim düzenlemesi) kritik bir öneme sahiptir. Toprak dinamik bir yapı olup, biyolojik çeşitliliğe destek amacıyla önemli işlevler üstlenir (Semenov and Đukić, 2020).

Toprak, dünyanın ekolojik dengesi üzerinde önemli bir yere sahiptir. Bitkilerin kökleri sayesinde su ve besin maddelerinin alımını gerçekleştirerek birincil üreticilerin gelişimini sağlar. Bu bitkiler, otçul hayvanlardan etçillere kadar tüm canlıların besin kaynağını oluşturur. Bununla birlikte toprak, karbon döngüsünün önemli bir parçasıdır. Bitkilerin ve organik materyallerin ayrışması ile karbonun tutulmasını, atmosferdeki karbondioksit miktarının düzenlenmesinde rol oynar (Fenton, 1947).

Ekosistemin sürdürülebilirliği açısından toprakta bulunan mikroorganizmalar, mantarlar ve solucanlar, önemli bir yere sahiptir. Bu organizmalar, organik maddeleri ayrıştırarak toprağın verimliliğini yükseltir ve bitkilerin ihtiyacı olan besin maddelerini kullanılabilir duruma getirir. Bazı mikroorganizmalar, bitkilerin kökleriyle simbiyotik ilişkiler oluşturarak besin ve su alımını artırırken, atmosferik azotu bağlayan bakteriler de topraktaki azot

döngüsüne destek olur. Bu biyolojik olaylar, toprağın sağlıklı ve verimli olması için sürdürülebilir tarım uygulamalarına yardımcı olur (Tan et al., 2022).

Toprak, çevresel kirliliğin en aza indirilmesinde doğal bir filtre görevi görerek ekosistem sağlığını destekler. Ağır metaller, pestisitler ve başka kirleticiler, toprak içindeki biyolojik ve kimyasal süreçler yoluyla pasif duruma getirilebilir. Örnek olarak, bazı toprak bakterileri toksik bileşikleri biyolojik olarak ayrıştırarak zararsız duruma getirirken, kil mineralleri ve organik madde, ağır metalleri bağlayarak yeraltı sularına bulaşmasını önleyebilir (Cárceles Rodríguez et al., 2022). Toprağın bu arıtma yeteneği, su kaynaklarının muhafazasına ve çevresel kirliliğin azaltılmasına katkıda sağlar.

Tarım alanları, doğal ve insan kaynaklı sebeplerle ciddi risklerle karşı karşıyadır. Toprak bozulması, tuzlanma, erozyon ve organik madde eksikliği gibi durumlar, tarımsal üretimi ve ekosistem sağlığını olumsuz etkileyerek sürdürülebilir gıda üretimini zorlaştırmaktadır. Yine, iklim değişikliği gibi küresel olaylar da toprak sağlığı üzerinde etkilidir (Kuo et al., 1997). Bu sebeple, tarımsal üretimde karşı karşıya kalınan toprak kaynaklı problemlerin nedenleri ve sonuçları analiz edilerek uygun çözümler geliştirilmelidir.

Toprak erozyonu, su ve rüzgarın da etkisiyle üst toprak tabakasının taşınması ile meydana gelen bir durumdur. Eğimli arazilerde ve bitki örtüsünün az olduğu yerlerde erozyon daha yaygındır. Topraktaki organik maddeyi ve besin elementlerini uzaklaştıran erozyon, tarımsal verimi azaltır ve ekosistem sağlığını olumsuz etkiler (Gómez et al., 2018b).

Toprak bozulması fiziksel, kimyasal ve biyolojik özelliklerde gözlemlenen olumsuzluklar sonucunda verimliliğinin etkilenmesidir. Toprak bozulmasının nedenleri; aşırı toprak işleme, yoğun kimyasal gübre, uygun olmayan sulama teknikleri ve pestisit kullanımı, monokültür tarımı şeklindedir (Techen et al., 2020).

Tuzlanma, öncelikle uygun olmayan sulama teknikleri sebebiyle tarım topraklarında gözlemlenen ciddi bir problemdir. Yeterli olmayan drenaj, sulama ile taşınan tuzların toprağın üzerinde birikmesine ve bitkilerin su alımını zorlaştırarak büyüme ve gelişmesinin engellenmesine sebep olur. Tuzluluk, özellikle kurak ve yarı kurak yerlerde ciddi bir tehdit oluşturmaktadır (Hasan Khan Robin et al., 2016).

Yanlış tarım teknikleri ve aynı ürünün sürekli üst üste ekilmesi (monokültür) nedeniyle ortaya çıkan bir problem de besin kaybıdır. Toprakta devamlı olarak aynı besin maddelerinin harcanması, eksikliklere yol açar ve bitkilerin gelişimini engeller. Besin maddesi eksikliğinin önüne geçmek için toprak analizine göre besin takviyeleri, dengeli gübreleme, ve ekim nöbeti gibi uygulamalara yer verilmelidir (Fayiah et al., 2019).

İklim değişikliği, tarım topraklarında olumsuz etkileri sebep olmaktadır.Yükselen sıcaklıklar, düzenli olmayan yağış rejimleri ve farklı hava olayları, toprak nem dengesini değiştirerek verimliliği azaltabilir. Şiddetli kuraklık, toprakta organik madde azalmasına ve su tutma kapasitesinin azalmasına Zemin hazırlarken, şiddetli yağışlar ve seller de erozyonu tetikleyebilir. Bunun yanında, yükselen sıcaklıklar topraktaki mikroorganizmaların dengesini değiştirip, toprak sağlığını olumsuz etkileyebilir (Semenov and Đukić, 2020; Cárceles Rodríguez et al., 2022).

İklim değişikliğinin olumsuz etkilerini engellemek ve toprak sağlığının devamlılığı için sürdürülebilir tarım tekniklerinin tercih edilmesi gerekmektedir. Bilinçli toprak işleme, organik madde kullanımının artırılması, su tasarrufunu sağlayan sulama teknikleri ve karbon tutulumunu sağlayan tarımsal teknikler, iklim değişikliğinin olumsuz etkilerini en aza indirmede önemli stratejilerdendir (Abbas et al., 2017; 2020).

Uzun vadeli tarımsal üretimin devamlılığı açısından verimli ve sağlıklı topraklar, önemli bir role sahiptir. Öte yandan, hatalı tarım teknikleri, iklim değişikliği ve doğal bozulma, tarımsal toprakların verimliliği ve ekolojik dengesinde bir tehdit oluşturmaktadır. Bu durumda, toprağın korunması ve iyileştirilmesi için başlıca stratejiler arasında sürdürülebilir toprak yönetimi teknikleri, geleneksel ve modern toprak koruma teknikleri ile organik ve rejeneratif tarım teknikleri, yer almaktadır (Dumanski and Peiretti, 2013; Cárceles Rodríguez et al., 2022).

Minimum toprak işleme, toprağın fiziksel yapısını koruyarak erozyon riskini azaltırken, örtü bitkileri ve ekim nöbeti uygulamaları, toprağın organik madde içeriğini artırarak biyolojik çeşitliliği destekler. Bununla birlikte, tarımsal su yönetiminin doğru yapılması ve dengeli gübre kullanımı, toprak sağlığını iyileştirmek için önemli bir faktörlerdir (Mishra et al., 2018; Techen et al., 2020). Sürdürülebilir toprak yönetimi, doğal kaynakların ölçülü olarak kullanılması, toprak verimliliğinin muhafazası ve uzun süreli tarımsal üretimin desteklenmesi için geliştirilen bir dizi yöntem ve stratejiyi içermektedir. Bunlar arasında minimum toprak işleme, örtü bitkilerinin kullanımı, ekim nöbeti ve kompost uygulamaları bulunmaktadır.

Yıllardır çiftçiler tarafından uygulanan ve doğal süreçlerle uyumlu olan teknikler, geleneksel toprak koruma yöntemleridiri Teraslama, eğimli arazilerde toprak kaybını önlemek için kullanılan bir yöntemdir ve özellikle suyun düzenli bir şekilde toprağa nüfuz etmesini sağlayarak erozyonun önüne geçer. Yeşil gübreleme ise, toprağa azot ve diğer besin maddelerini kazandıran bitkilerin yetiştirilmesi ve toprağa karıştırılması esasına dayanır (Abbas et al., 2020).

Modern tarım biyolojik gübreler, kimyasal gübrelere alternatif olarak geliştirilmiş ve toprak mikrobiyotasını destekleyerek verimliliği artıran bir uygulamadır. Hassas tarım uygulamaları, sensörler ve veri analitiği kullanarak toprak nemi, besin seviyeleri ve bitki gelişimi hakkında bilgi sağlar ve böylece gübre ve su kullanımını optimize eder. Yine, koruyucu tarım uygulamaları kapsamında doğrudan ekim (no-till farming) yöntemi, toprağın yapısını bozmadan ekim yapılmasını sağlayarak toprak organik madde kapsamını ve su tutma kapasitesini artırmaktadır (Kraut-Cohen et al., 2020; Muhammad et al., 2021).

Kimyasal gübreler, pestisitler ve genetiği değiştirilmiş organizmalar (GDO) kullanmadan yapılan bir tarım sistemi olan organik tarım, toprak sağlığını koruyarak biyolojik çeşitliliği artırırken, su kaynaklarının kirlenmesini önlemeye de katkı sağlamaktadır (Fayiah et al., 2019). Bu sistemde doğal gübreler, biyolojik mücadele yöntemleri ve ekim nöbeti gibi teknikler öne çıkmaktadır.

Toprak ekosistemlerini iyileştirmeye yönelik uygulamalar bütününü ifade eden rejeneratif tarım ise, sürdürülebilir tarımdan bir adım öteye geçer. Toprak organik madde içeriğinin artırılması, mikrobiyal yaşamın desteklenmesi, otlatma yönetimi ve ağaçlandırma gibi yöntemler rejeneratif tarımın temel bileşenleridir. Bu yöntem, karbon tutumunu artırarak iklim değişikliği ile mücadelede önemli bir rol oynar. Bu uygulamalar sayesinde, tarımsal üretimin ekosistem üzerindeki olumsuz etkileri en aza inerken, toprağın kendini yenileyebilmesi mümkün olmaktadır (Voisin et al., 2024).

Toprağın korunması ve iyileştirilmesi tarımsal üretimin sürdürülebilirliği için büyük bir ihtiyaçtır. Geleneksel ve modern toprak koruma tekniklerinin entegre edilmesi, organik ile rejeneratif tarım uygulamalarının yaygınlaştırılması ve sürdürülebilir toprak yönetimi yaklaşımlarının benimsenmesi tarımsal verimliliği artırırken doğal kaynakların korunmasını sağlayacaktır. Bu stratejiler, hem mevcut tarım sistemlerinin iyileştirilmesine hem de gelecekte sağlıklı ve verimli toprakların devamlılığına katkıda bulunacaktır.

Tarım arazilerinde toprak kalitesini artırmak, erozyonu önlemek, su tutma kapasitesini iyileştirmek ve ana ürün ekimi dışında toprağın korunması, iyileştirilmesi amacıyla yetiştirilen bitkiler örtü bitkileri olarak bilinmektedir. Bu bitkiler, tarımsal sistemlerin sürdürülebilirliğini artırarak toprak sağlığını destekleyen önemli bir araç olarak kabul edilmektedir. Genellikle baklagiller (yonca, fiğ, mercimek) toprak azotunu artırırken, tahıllar (çavdar, yulaf, arpa) organik madde katkısı sağlar ve erozyonu önler. Yeşil gübre bitkileri (baklagiller), tahıllar, çim türleri ve çeşitli otlar gibi farklı türlerden oluşabilir. Çok yıllık çayır bitkileri ise uzun vadeli toprak iyileştirme sağlamak için tercih edilir (Fageria et al., 2005).

Toprağın besin dengesini iyileştirerek uzun vadeli verimliliği artıran örtü bitkileri, toprağın su tutma kapasitesini geliştirirken, yüzeydeki yeşil örtü erozyonu önleyerek toprak kaybını azaltır. Organik madde miktarını artırarak toprak yapısını iyileştirir ve karbon tutulmasına katkı sağlayarak iklim değişikliğiyle mücadelede önemli bir rol oynar. Bununla birlikte, örtü bitkileri tarımsal ekosistemlerde biyolojik çeşitliliği artırarak yararlı mikroorganizmalar, böcekler ve farklı toprak canlıları için yaşam ortamı sağlar (Bielenberg et al., 2023). Tarla rotasyon sistemlerinde örtü bitkileri, farklı türlerin dönüşümlü olarak ekilmesiyle toprak sağlığını koruma açısından büyük fayda sağlar. Örtü bitkilerinin kullanımı, bölgesel iklim ve toprak koşullarına bağlı olarak değişkenlik gösterebilir. Genellikle doğrudan ekim yöntemi ile toprağa karıştırılmadan yetiştirilir ve ana ürün ekimi öncesinde toprağa dahil edilir. Bazı bölgelerde yapılan araştırmalar, örtü bitkilerinin uzun vadede toprak organik maddesini artırdığını, erozyonu önemli ölçüde azalttığını ve su tutma kapasitesini iyileştirdiğini göstermektedir. Örneğin, ABD'de yapılan çalışmalar, örtü bitkilerinin kullanıldığı tarlalarda organik madde miktarının %20'ye kadar arttığını ortaya koymuştur. Avrupa'da ise bazı çiftçiler, toprak yapısını iyileştirmek ve kimyasal gübre ihtiyacını azaltmak amacıyla baklagil ağırlıklı örtü bitkileri karışımlarını tercih etmektedir (Schnitkey et al., 2023).

Örtü bitkilerinin tarımsal üretim süreçlerine entegrasyonu, toprak kalitesinin korunmasına ve iyileştirilmesine katkıda bulunur (Scavo et al., 2022). Örtü bitkileri, tarımsal üretim sistemlerine entegrasyonunda farklı yöntemlerle kullanılabilir. Örtü bitkileri, ana ürün öncesi, sırasında veya sonrasında ekilerek toprağın besin maddesi dengesini düzenler, organik madde içeriğini artırır ve erozyonu önler. Örtü bitkileri bazı uygulamalarda, ana mahsul ekimi öncesinde yeşil gübre olarak toprağa karıştırılırken, bazı sistemlerde doğrudan malçlama amacıyla yüzeyde bırakılır (Kuo et al., 1997).

Baklagiller ve otlar kurak ve yarı kurak bölgelerde tercih edilirken, nemli bölgelerde su tutma kapasitesi yüksek bitkiler daha yaygın olarak kullanılmaktadır (Aparecida et al., 2018). Kumlu topraklarda su tutma kapasitesini artırmak amacıyla lifli kök yapısına sahip bitkiler tercih edilirken, ağır killi topraklarda toprağın havalanmasını artıran türler öne çıkmaktadır. Örtü bitkilerinin kullanımı, bölgesel iklim koşulları ve toprak yapısına bağlı olarak değişiklik göstermektedir. Bununla birlikte, toprağın mevcut besin durumu da örtü bitkisi seçiminde belirleyici bir faktördür. Organik madde eksikliği bulunan alanlarda tahıllar ve geniş yapraklı otlar tercih edilirken, azot bakımından fakir topraklarda baklagil türleri daha etkili olabilir.

Örtü bitkilerinin uygulanmasında bazı zorluklarla karşılaşılmaktadır. Bunlar arasında, çiftçilerin örtü bitkilerinin faydaları konusunda yeterince bilgi sahibi olmaması, ekim ve yönetim süreçlerinde karşılaşılan teknik zorluklar, ana ürünle rekabet edebilmeleri, bazı örtü bitkilerinin su tüketiminin yüksek olması yer almaktadır. Bununla birlikte, örtü bitkilerinin uygun şekilde yönetilmemesi durumunda, bazı hastalık ve zararlılara ev sahipliği yapabileceği veya yabancı otlarla rekabeti artırabileceği bilinmektedir.

Çiftçilere yönelik eğitim programları, örtü bitkilerinin daha etkin ve verimli şekilde uygulanmasını sağlarken, teknolojik gelişmelerin entegrasyonu ile hassas tarım teknikleri kullanılarak örtü bitkilerinin daha optimize bir şekilde yönetilmesi mümkün hale gelmektedir. Tarımda sürdürülebilirliği artırmak açısından bakıldığında, örtü bitkilerinin kullanımını teşvik eden politikalar ve teşviklerin gerekli olduğu düşünülmektedir. Uzun vadede, örtü bitkilerinin daha yaygın şekilde benimsenmesi, su kaynaklarının korunmasına katkıda bulunacak, toprak sağlığını iyileştirerek verimliliği artıracak ve tarımın çevresel etkilerini en aza indirecektir.

Sonuç ve Öneriler

Bu çalışma, örtü bitkilerinin tarımsal üretimde toprak sağlığını koruma ve iyileştirme potansiyelini vurgulamaktadır. Örtü bitkileri, su tutma kapasitesini iyileştirerek kuraklık koşullarında dayanıklılığı artırmakta, toprak organik madde içeriğini artırarak verimliliği desteklemekte ve erozyonu önleyerek toprağın uzun vadeli korunmasına katkı sağlamaktadır. Yine, bu bitkiler tarımsal ekosistemlerde biyolojik çeşitliliği teşvik ederek sürdürülebilir üretim sistemlerinin temel unsurlarından biri olmaktadır.

Örtü bitkilerinin tarımsal sistemlere entegrasyonu, kimyasal gübre ihtiyacını azaltarak toprağın doğal yapısını korurken aynı zamanda çevre dostu bir üretim süreci oluşturmayı sağlamaktadır. Bu uygulamalar, ekosistem sağlığını destekleyerek tarımın uzun vadede daha sürdürülebilir hale gelmesine yardımcı olmaktadır.

Örtü bitkilerinin daha yaygın şekilde benimsenmesi ve yönetim stratejilerinin geliştirilmesi tarımsal sürdürülebilirlik açısından değerlendirildiğinde, büyük bir gerekliliktir. Gelecekte, çiftçilerin bu konuda bilinçlendirilmesi, bilimsel araştırmaların artırılması ve örtü bitkilerinin kullanımını teşvik eden politikaların uygulanması, tarımsal üretimin çevreye duyarlı bir şekilde devam etmesini sağlayacaktır. Tarımsal verimliliğin anahtarı sağlıklı topraklar olup, örtü bitkileri gibi doğal çözümler, sürdürülebilir tarımın temel taşlarından biri olarak değerlendirilmelidir. Bu nedenle, örtü bitkilerinin tarım sistemlerine entegrasyonu ve kullanımının yaygınlaştırılması büyük önem taşımaktadır.

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ID: 501

Advancing Banana Cultivation Through Multispectral Imaging and Precision Agriculture: A Scalable Algorithm for Crop Optimization

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Abstract

Precision agriculture has emerged as a transformative approach to modern crop management, integrating advanced technologies to optimize productivity, resource efficiency, and sustainability. This research presents a novel multispectral image classification algorithm specifically designed for banana cultivation (*Musa* AAA), combining aerospace technology, spectral analysis, and machine learning to address critical challenges in tropical agriculture. The study was conducted in a commercial banana plantation, where high-resolution visible and near-infrared spectral data were acquired using state-of-the-art optical sensors mounted on unmanned aerial vehicles (UAV). The methodology employed the Normalized Difference Vegetation Index (NDVI) as a primary tool for crop zoning and health assessment. Through sophisticated image processing techniques implemented in Python, we generated precise vegetation and soil fragmentation masks at the administrative plot level, enabling spatial resolution in crop monitoring. The algorithm successfully identified subtle variations in plant health and nutritional status across different sectors of the plantation, allowing for the creation of detailed sub-plots with distinct agronomic requirements. Comprehensive statistical analysis of spectral data provided actionable insights into plot-specific needs, facilitating data-driven recommendations for fertilizer application, irrigation scheduling, and pest management. This work represents a significant advancement in precision agriculture for banana cultivation, offering a scalable solution that can be adapted to diverse growing conditions in Ecuador and the around the world. The integration of aerospace technology with advanced analytics not only improves production efficiency but also contributes to sustainable farming practices by minimizing unnecessary resource inputs. With further development, this approach could be extended to other tropical crops, potentially revolutionizing agricultural practices in developing nations. The study underscores the critical role of spectral technology in addressing global food security challenges while promoting environmental stewardship.

Key Words: *Multispectral imaging, Precision agriculture, NDVI, Banana crop optimization*

ID: 502

Seed Coating and Sustainable Agriculture

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Abstract

Increased productivity in agriculture is possible with technological developments. One of these technologies is the protection of seed quality. Synthetic seeds are artificially encapsulated plant propagation material. It is coated with special substances containing nutrients and protective compounds. The main goal of seed coating technologies is to enable small seeds to grow to larger and uniform sizes. Synthetic seed production offers the opportunity for a cheap and practical tissue culture production technique. Plant nutrients, fungicides, insecticides, herbicides and beneficial organisms can be added to the seed coating material. Seed coating technologies are mostly carried out as pelletizing, film coating or pellet+film coating methods. Owing to the seed coating method, the performance of the seeds for germination will increase and thus the ability of the plants to combat against possible diseases and pests during the germination and seedling periods will increase. One of the difficulties in agricultural practice and research today is how to cope with biotic and abiotic stress conditions, especially climatic changes, in an economically and environmentally sustainable approach. In this prepared study, information is given about seed coating and its applications in field crops.

Key Words: *Alternative control, Biofortification, Priming, Synthetic seed, Sustainable agriculture*

1. Introduction

The effective integration of technological advances into production processes is an important and also remarkable factors that increase productivity of agriculture. Among these innovations, especially the protection and improvement of seed quality has a critical role in terms of sustainable agricultural practices (Bennett et al., 2013). Seed coating technologies have been developed to increase productivity in agricultural production; however, they have made it possible for plants to become more resistant to environmental stress factors (Pedrini et al., 2017). That kind of technologies are not only increasing the germination ratio, but also they support to management of fields owing to promoting the homogeneous seed emergence (Halmer, 2006). Various nutrients, insecticides and also fungicides incorporated to coating based materials protect the plants counter to pests and diseases during the early development periods (Colla et al., 2015).

According to another related research, it was reported that combination of seed coating technologies by biologic based coating materials contributed to improvement of soil health besides increase in activity of soil microbials (Bashan et al., 2014). Particularly, hydrogel-based type coating materials are known as increasing the capacity of moisture retention in seeds under drought conditions, therefore increasing of the plant tolerance against water stress (Gao et al., 2019).

Seed coating technology cause to significant increases in seed germination percentage, and so improves the plant ability to combat wtih pests and diseases on germination period besides seedling period (Taylor et al., 1998). The main focus for seed coating technology is providing of reach to homogeneous and larger size to small seeds, therefore increase in efficiency and also success to sowing ratio (Haciyusufoğlu et al., 2015). Plant based nutrients, insecticides, fungicides, herbicides and also the beneficial microorganisms may also be integrated to seed coating materials as well (Rufino et al., 2013; Corlett et al., 2014).

According to many literature related with seed coating, the positive effects reported for germination ratio, development of root and shoot, growing of seedling, accumulation of dry matter, area of leaf and yield as well have been reported (Tavares et al., 2013; Dumanoğlu and Öztürk, 2022). Moreover, using of coated seeds has great importance in the sedd breeding based researches. Healthy plants that are obtained from the quality seeds can remarkable contribute for more controlled and also efficient results in the breeding programs (Sarıçam et al., 2018). In this study, prepared in the light of the scientific literature in question, scientific findings about seed coating and its applications in sustainable agricultural systems were presented.

2. Seed Coating Technologies

2.1. Definition and Importance of Seed Coating

Seed coating technology developed for the aim of providing more healthy and also efficient growing by additşon of variegated nutrients, protection based components and growing regulators to the exterior layer of seeds (Taylor & Min, 1991). This technique is especially important for small seeds in order to ensure their uniform distribution

in the field and to support their early development. Problems arise in machine sowing of seeds with small diameter, non-spherical shape and hairy tops compared to large diameter, smooth shaped seeds. In order to make the shape of such seeds more spherical, to increase their diameter, and to eliminate the hair and thorn-like appearance on them, it is possible to eliminate the negativities by covering the seeds with certain substances. The process of coating the seeds with certain substances in this way can be called seed coating, and the maintenance and improvement of the existing quality of the seed after harvest and the preservation of the value of the seed can be called post-harvest practices, which can be grouped as good seed storage, pre-sowing practices (priming), seed conditioning and coating technologies (pellet and film coating).

2.2. Seed Coating Techniques

Seed coating methods are techniques developed to support the early development of the plant and provide protection against environmental stress conditions. These methods are carried out by applying various substances to the outer surface of the seed and can be broadly categorized into four main groups: pelleting, film coating, pellet+film and bio-coating. Pelleting provides ease of mechanical sowing, especially for small and irregularly shaped seeds, by shaping them into a more uniform form so that sowing depth and uniform emergence can be controlled (Rehman and Farooq, 2016). Film coating, on the other hand, allows nutrients, pesticides or microbial preparations to be applied to the seed with a very thin layer without disturbing the natural shape of the seed and offers the advantage of controlled release (Scott, 1989). Pellet+film coating is one of the most advanced methods, combining these two methods to provide both physical protection and biochemical support (Pill & Finch-Savage, 1988). Bio-coating activates the plant's immune system against biotic and abiotic stresses at an early stage by applying beneficial microorganisms (e.g. Rhizobium, Trichoderma, Bacillus spp.) to the seed surface (Bashan et al., 2014). These methods can be flexibly adjusted according to environmental conditions, crop type and the objectives of the producer, contributing to the sustainability goals of modern agriculture.

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2.2.1. Film coating

Film coating is a modern coating method that provides seed protection and improvement through a thin, adhesive and often clear layer applied to the seed surface (Scott, 1989). Initially developed in the pharmaceutical and food industry, this technology was later successfully applied to seed coating applications in agriculture. During the film coating process, the size and shape of the seeds remain largely unchanged, while active substances such as nutrients, fungicides, insecticides, biostimulants and color pigments can be brought into contact with the seed. One of the most commonly used equipment is the rotary coater, in which film-forming polymers are formulated to dissolve or disperse the active ingredient and applied to the seeds in a controlled manner. One of the main advantages of film coating is the high application recovery (about 90%) and uniform distribution on the seed surface. It also improves the flow ability of the seeds, offering advantages in terms of mechanical performance during both processing and planting. The weight gain achieved by film coating is typically 2% to 5% of the seed weight, which allows for active ingredient transportation without significantly affecting physical performance. Research has shown that maize seeds coated using proprietary film coating polymers (e.g. PolySeedCF) reduce dust formation and minimize environmental impacts by preventing leaching of applied insecticides. With these characteristics, film coating is an advanced seed treatment technology with both ecological and economic benefits.

2.2.2. Pelletization

Pelletization is a method of seed coating that is applied especially to small and irregularly shaped seeds in order to give them a smooth, round and evenly sized form. Thanks to this technique, the seeds become larger and more uniform, so that they can be contacted with the soil with high precision and homogeneity in precision planters (Halmer, 2006). During the pelleting process, the seed usually remains in the center as a kernel and inert materials such as lime, clay, cellulose, chalk, starch and polymers are added as a covering blanket. Nutrients, plant growth regulators and preservatives can also be added. Pelleting significantly improves seed dispersal, sowing depth and emergence rate, which is of great benefit to growers with germination problems, especially for small-seeded species such as carrots, lettuce and alfalfa (Gray & Steckel, 1999). This method also improves germination success

by increasing seed access to water and nutrients in harsh environmental conditions such as drought or nutrient deficiency. However, the quality of the coating material and the solubility time should be carefully adjusted. Otherwise, undesirable effects such as delayed germination may occur. Advanced pelleting techniques make it possible to coat seeds with biological and chemical protection agents, creating a multi-purpose application area.

2.2.3. Pellet + Film Coating

It is one of the most developed combinational approaches among seed coating technologies. In this method, the pelletizing process gives the seeds physical integrity and a standardized form, while the film coating applied on top of it enables the precise addition of pesticides, nutrients or biological agents to the outer surface of the seed (Pill & Finch-Savage, 1988). Particularly for small seeds with low germination potential, this method optimizes both emergence rate and seedling development. Thanks to the controlled release of the film coating, the substances needed by the seed can be delivered directly with minimal impact on the environment.

2.2.4. Bio - Coating

It is an innovative technique in which seeds are coated with useful microorganisms to increase both the nutritional capacity of the plant and its resistance to environmental stresses. Among the microorganisms used in this method, species such as *Rhizobium*, *Azospirillum*, *Trichoderma* and *Bacillus subtilis* stand out. These biological agents compete with harmful pathogens in the soil and inhibit their growth, while at the same time producing phytohormones that promote plant growth (Bashan et al., 2014). Bio-coating not only increases yields but also supports sustainable agriculture by maintaining soil microbial diversity and health. The fact that it helps to reduce chemical inputs makes it often preferred in ecological agriculture practices. *Rhizobium* species, on the other hand, establish symbiotic relationships, particularly with legumes, and bind atmospheric nitrogen, making it available to the plant and reduce the need for chemical fertilizers (Zahran, 1999). For example, *Trichoderma* spp. both promote root growth and provide prevention against diseases such as root rot (Harman, 2000).

3. Seed Coating Applications in Field Crops

3.1. Improving Germination and Seedling Development

Seed coating technologies play a direct impact role on germination and young seedling development. The germination process, especially in small and sensitive seeds, can be negatively affected by environmental stress factors or soil conditions. Coated seeds minimize these adverse effects by containing moisture retaining polymers, growth promoting substances (e.g. gibberellin, cytokinin), nutrients and protective agents (Halmer, 2006). Techniques such as pelleting and film coating regulate the physical interaction of the seed with its environment, promoting uniform water uptake and regular oxygen exchange. They promote rapid and simultaneous germination (Pedrini et al., 2017). Micronutrients such as phosphorus and zinc, which are provided locally around the seed, accelerate root development and enable the formation of more robust and durable individuals during the seedling period (Cakmak and Cakmak, 2008). Seeds developed with these technologies show high performance even under conditions that delay germination such as drought and low temperatures. Therefore, post-sowing emergence rate increases and yield and quality become more predictable and sustainable.

3.2. Protection Against Diseases and Pests

Seed coating treatments provide the first line of defense against pathogens and harmful organisms that plants may encounter during early developmental stages. Thanks to the fungicides and insecticides applied to the surface of the coated seeds, protection is provided from the first moment the seed comes into contact with the soil. This is an effective measure against soil-borne diseases (e.g. *Rhizoctonia solani*, *Fusarium* spp., *Pythium* spp.) and pests (e.g. earthworms and insect larvae targeting seedlings). Furthermore, the chemical agents, biological control based mechanisms are also activated by addition of the beneficial microorganisms likewise *Pseudomonas fluorescens*, *Trichoderma* sp. and *Bacillus subtilis* to seed coating based materials (Harman, 2000; Colla et al., 2015). This type of biological based agents provide to protection of both directly competing with pathogens and stimulation of the plant immune systems. Thus, it is possible to reduce pesticide use and increase environmental sustainability. This protective effect allows plants to develop better under stress and can positively affect crop yields.

3.3. Increasing Nutrient Uptake and Plant Nutrition

The enrichment of materials used in seed coating technologies with plant nutrients is of great importance to provide optimal nutrition of plants during early development. The nutrient needs of the seed during germination and seedling development can be met to a limited extent due to the incomplete development of the root system. At this stage, micronutrients and macronutrients (especially phosphorus, zinc, potassium and iron) applied directly to the seed both support plant growth and increase the bioaccessibility of nutrients present in the soil but difficult to be taken up by the plant (Welch & Graham, 2004). For example, it has been observed that both germination rates and early root elongation of wheat seeds coated with zinc significantly increased (Cakmak, 2008). Furthermore, when plant growth-promoting amino acids, humic substances or biostimulants are incorporated into coating materials,

root growth, nutrient absorption and overall plant resilience are positively affected (Colla et al., 2015). This practice supports environmental sustainability while reducing the need for fertilizer use, especially in poor or nutrient-limited soil conditions.

3.4. Resistance to Abiotic Stress Conditions

Abiotic based factors likewise drought, salinity and also temperature welded stresses, which are increasing with climate change in agriculture, pose serious threats to plant growth and productivity. The seed coating technology was used as an effective tool to increase plant tolerance to these stress conditions. By adding osmotic regulators (e.g. glycine betaine), antioxidants and biological agents to coated seeds, better germination and development of seeds under stress conditions can be achieved (Ashraf & Foolad, 2007). Additionally, some of the biological coatings facilitate the plant to combat oxidative stress by activating its defense mechanisms (Tuğrul and Kaya 2020). The mentioned practices are highly valuable to ensure the sustainability of production, especially for the marginal soils besides variable environmental conditions. Particularly, the hydrogel-containing coatings reduce water stress by retaining moisture in the micro-environment around the seeds and facilitate the plant access for water (Gao et al., 2023).

4. Conclusions

Various types of the seed coating technology are known as a versatile contribution to the productivity, environmental sustainability and stress management aims of modern agriculture. Applied through various methods such as film coating, pelleting, bio-coating and their combinations, this technology not only increases germination rates, but also promotes healthy development of young seedlings, optimizes nutrient uptake and makes plants more resilient to biotic and abiotic stress factors.

In the field crop practices, the adaptability of seed coating to species and environmental conditions increases the widespread applicability of this technology. Particularly, the bio-coatings containing microorganisms offer a solution that is compatible with sustainable agricultural policies by making it possible to reduce chemical inputs. Therewithal, the nutrients, growth regulators and protective agents incorporated into coating based materials directly provide to support of plant requirements during the development period, create potentials for high yields. In the future, the development of environmentally friendly and biodegradable coating materials, supported by digital solutions integrated with precision agriculture practices, and the dissemination of awareness-raising trainings at farmer level will further increase the effectiveness of this technology. Seed coating technologies are not only a production tool, but also a candidate solution to global challenges such as climate change, soil degradation and reducing the use of agricultural chemicals. In this context, it is of great importance to continue research and adapt the technology to local conditions.

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The Use of Capsule Houses in Landscape Design Studies

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Abstract

The rapid development of urbanization has provided significant opportunities for the advancement of architectural landscape design while simultaneously bringing about major challenges. This pace of development has led to the rapid emergence of new urban areas and an endless array of new construction projects. For those longing for natural environments, structures such as bungalows, caravans, capsule houses, and tents have become attractive alternatives. Capsule houses stand out as innovative structures offering sustainable, aesthetic, and functional solutions in modern landscape design. Thanks to their nature-friendly designs and portable structures, they offer extensive usability in rural, natural, and recreational areas.

Natural and cultural landscape areas, which possess natural, aesthetic, functional, and economic features, provide various usage opportunities. Demand for natural spaces such as waterfronts, rural areas, historical sites, and national parks is increasing day by day. The aim of this study is to develop design proposals for living spaces to be created in these mentioned platforms. Different models will be created using SketchUp software.

Keywords: *Capsule houses, Landscape, Bungalows, Urbanization, Natural areas*

Peyzaj Tasarım Çalışmalarında Kapsül Evler Kullanımı

Özet

Hızlı kentleşme gelişimi, mimari peyzaj tasarımının gelişimi için büyük fırsatlar sunmuş, ancak buna paralel olarak çeşitli büyük zorlukları da beraberinde getirmiştir. Bu tür bir gelişim hızı, insanlara yeni kentsel alanların hızla ortaya çıkması, bitmek bilmeyen yeni inşaat projeleri gibi unsurlar sunmaktadır. Doğal ortamlara özlem duyanlar için bungalov evler, karavan ve kapsül evler, çadırlar vb. ilgi çeken mekanlar oluşturmaktadır. Kapsül evler, modern peyzaj tasarımında sürdürülebilir, estetik ve işlevsel çözümler sunan yenilikçi yapılar olarak öne çıkmaktadır. Doğayla uyumlu tasarımları ve taşınabilir yapıları sayesinde kırsal, doğal ve rekreasyon alanlarında geniş kullanım imkânı sunarlar.

Doğal, estetik, fonksiyonel ve ekonomik özelliklere sahip doğal ve kültürel peyzaj alanları farklı kullanım alanları sunmaktadır. Su veya deniz kenarları, kırsal alanlar, tarihi alanlar, milli parklar vb. doğal alanlara talepler günden güne talep artmaktadır. Bu çalışmanın amacı, adı geçen paltformlarda yaşam mekanları için oluşturulacak tasarım çalışmaları için öneriler geliştirilecektir. SketchUp yazılımı kullanılarak farklı modellemeler oluşturulacaktır.

Anahtar Kelimeler: *Kapsül evler, Peyzaj, Bungalov evler, Kentleşme, Doğal alanlar*

Giriş

Türkiye'de nüfus hızla artış göstermektedir. Şehirleşmenin hızla arttığı dönemimizde insanların yerleşim alanlarına olan ihtiyaçları sürekli artmaktadır. İmarlaşma alanlarına olan gereksinimi karşılamak için, kentlerin yeşil ve tarım alanları kullanılmaktadır. Tarım alanlarının yerlerini apartmanlar, işyerleri vb. nin yerini beton yapılar almaya başlamıştır. Binalar arasında kullanıma uygun olmayan dar mekanlar ise yeşil alan olarak değerlendirilmektedir. Avrupa standartlarına göre uygun ekolojik ortamlar için kişi başına düşen yeşil alan miktarı 9-10m^2 olması gerekirken Türkiye'de genel olarak bu miktar çok fazla düşüş göstermektedir. Yasal yönetmelklerde de belirlenen yeşil alan miktarı 10$m^{2'}$ dir.

Aksoy, 2001' de yaptığı çalışmada, 1999 yılında "İmar Planı Yapılması ve Değişikliklerine Ait Esaslara Dair Yönetmelikte kişi başına düşen yeşil alan miktarı 10 m^2 'olarak belirlenmiştir.

Ülkemizde kentsel yeşil alanlar sistemi sadece nicelik olarak ele alındığı, özellikle yeşil alanların kentsel alanın tümünde eşit ve dengeli bir şekilde dağılmadığı, yeşil alanlar arasında organik bağlantıların olmadığı, erişilebilirliğin yetersiz olduğu ve kent içinde parçalı bir dağılım gösterdiği yaygın bir şekilde kabul görmektedir(Türker ve ark., 2022).

Bu yeşil alan sıkıntısı insanların yeşil alan bulmak, dinlenmek, rekreasyon faaliyetlerini gerçekleştirmek için yerleşim alanlarından daha uzak mekanlara gitme ihtiyacını beraberinde getirmektedir. İnsanlar özellikler, tatil dönemlerinde doğal ortamlarda yaşayabilmek için taşınabilir evler (karavan vb.), yada kırsal alanlarda bulunan kapsül veya bungalov evlere ihtiyaç duymaktadır. Gerek yaz gerekse kış tatillerinde otellerin olmadığı yada konaklama mekanlarının yetersiz olduğu mekanlarda kısa süreli konaklamalar için kapsül yada bungalov evler veya karavan park alanları daha da fazla talep görmektedir.

Günümüzde, Türkiyenin sosyal ekonomisi hızla ve zamanla değişmektedir. İnsanlar doğaya olan özlemi artmakta. İnsanlar, doğa ile özlemini giderebilmek için çok fazla paralar ödemektedirler. Ve insanların sosyal faaliyetler için talepleri günden güne artış göstermektedir. İyi tasarlanmış, insanların sosyal etkinliklerinin gerçekleştireceği mekanlar, oyun alanları, yeme içme mekanları ilgi alanının artmasını sağlamaktadır. Küçük alanlarda tasarlanan evler, çevreye duyarlı bir yaşam tarzını desteklerken otel konforunu da sunarak, tamamen bağımsız yaşam ortamı sunar. Bu evlerden birisi de kapsül evlerdir.

Kapsül evler, mikro ölçekte evlerdir. Çeşitli amaçlar için alternatif konut çözümleri sunarak, inşaat malzemeleri ve enerji tüketimi açısından daha düşük çevresel etki sağlar. Küçük boyutları sayesinde bu kompakt konutlar, yenilikçi tasarım çözümlerine ilham verir. Kapsül evlerin tasarlanmasında ana amaç, sürdürülebilirliği ve evrenselliği sağlayarak konteyner tarzı konutlardan ayrışan, taşınabilir bir mikro-ev tasarlamak ve üretmektir. İki kişiyi barındıracak ve farklı iklim koşullarında ihtiyaçlarını karşılayacak şekilde geliştirilen bu konut, Ecocapsule adı verilen benzersiz küresel bir tasarıma sahiptir. Bu şekil, yağmur suyunu en iyi şekilde toplarken enerji kaybını en aza indirir.

Kapsül evler, doğayla uyumlu, sürdürülebilir ve minimal yaşam alanları sunduğundan, peyzaj tasarımları da bu konsepti desteklemelidir. Hem estetik hem de fonksiyonel çözümler sunarak doğal çevre ile bütünleşen bir ortam oluşturmak mümkündür.

Kapsül evlerin, çevresinde kullanılan bitkiler, bulunduğu bölgenin ekosistemine uygun seçilmesi ile doğal türlerin kullanılması sağlanacaktır. Doğal bitki türleri kullanılarak hem ekolojik denge korunur hem de bakım maliyetleri düşer. Peyzaj tasarım çalışmalarında kullanılacak, doğal taşlar, ahşap yollar ve yeşil çatı uygulamaları ile doğal görünüm desteklenebilcek ve ekolojiye uygun mekanlar oluşturulacaktır.

Kapsül Evlerin Ekolojiye Katkısı

Kapsül evlerin gerek kırsal alanlarda gerekse kent ortamında kullanımının bir çok faydası vardır. Özellikle doğada yada farklı ortamlarda gezerek zaman geçirmek isteyenler genelde çadır, karavan tercih etmektedirler. Belirli günlerde kalmak isteyenler bungalov evlerini kullanmaktadırlar. Alternatif ve daha ekolojik olan kapsül evler yaygın olarak tasarlanması doğaya katkı sağlamaktadır. Kapsül evler, minimal yaşam felsefesini benimseyen ve doğayla iç içe bir yaşam sunan kompakt konut çözümleridir. Peyzaj alanında kullanımları, sürdürülebilirlik, doğal çevreye entegrasyon ve ekolojik yaşamı destekleme açısından büyük avantajlar sunmaktadır.

Kapsül evler, doğaya duyarlı yapıları sayesinde sürdürülebilir bir yaşam alanı sunarak ekolojiye önemli katkılarda bulunur. Geleneksel konutlara kıyasla daha düşük karbon ayak izi, enerji verimliliği ve doğal kaynak kullanımında tasarruf sağlamaları**,** onları çevre dostu bir alternatif haline getirir.Kapsül evlerin Doğaya katkıları şu şekilde sıralanabilir:

1. Sürdürülebilir Peyzaj Tasarımı

Peyzaj tasarım çalışmalarında kullanılan kapsül evler doğaya önemli katkı sağlamaktadır. Yağmur sularının korunması, Gri su kullanımı, Kompost alanı ve güneş ve rüzgara yön vermek amaçlı kullanılabilir.

- **Yağmur Suyu Hasadı:** Çatı yüzeyinden toplanan yağmur suyu, bitkilerin su ihtiyacının karşılanması için kullanılabilir.
- **Gri Su Kullanımı:** Mutfak ve banyo atık suyu, bitkilerin sulanması için arıtılarak yeniden değerlendirilebilir.
- **Kompost Alanı:** Kapsül evler yaşam ortamları oluşturacağı için organik atıkları değerlendirmek ve toprağı zenginleştirmek için kompost alanı oluşturulabilir.
- **Güneş ve Rüzgar Yönlendirme:** Rüzgar ve güneş yönü dikkate alınmadan yapılan tasarımlar insanları rahatsız edebilmektedir. Kapsül evlerin etrafında ypılacak bitkilendirme çalışmaları ile yaşam alanları stratejik olarak konumlandırılabilir.

2.Fonksiyonel ve Estetik Ögeler

- **Doğal Yollar ve Patikalar:** Ahşap, çakıl veya taş yürüyüş yolları ekleyerek kapsül eve erişimi kolaylaştırılabileceği gibi doğal görünüm alanları oluşturmaktadır.
- **Açık Hava Oturma Alanları:** Minimalist mobilyalarla doğayla iç içe yaşam alanları oluşturmak ekolojik mekanlar tasarlanabilir.
- **Gölgelendirme Elemanları:** Ağaçlar, pergolalar veya bitkilerle oluşturulan gölgelik alanlar, kapsül evin aşırı güneşten korunmasını sağlamaktadır.

3. Besin Üretimi ve Ekolojik Yaşam

- **Dikey Bahçeler:** Küçük alanlarda bile sebze ve ot yetiştirmek için ideal bir çözüm oluşturulabilir.
- **Permakültür Bahçesi:** Kendi kendine yeten bir sistem oluşturarak doğal gıda üretimini teşvik edebilir.
- **Arı ve Kuş Dostu Bitkiler:** Yerel ekosisteme katkı sağlayarak doğayla uyumlu bir yaşam alanı oluşturur.

4. Aydınlatma ve Enerji Kullanımı

- **Güneş Enerjili Aydınlatmalar:** Bahçe yolları ve oturma alanları için çevre dostu bir çözüm sağlayabilir.
- **Düşük Tüketimli LED Lambalar:** Işık kirliliğini önlerken enerji verimliliği sunmaktadır.
- **Rüzgar Türbinleri veya Güneş Panelleri:** Yenilenebilir enerji kaynakları ile kapsül evin enerji ihtiyacı karşılanabilir.

5. Doğayla Uyumlu Tasarım:

Kapsül evler, organik ve modern tasarım anlayışıyla doğal peyzajla bütünleşerek estetik bir görüntü oluşturur.

- Küresel veya aerodinamik şekilleri sayesinde rüzgar, su ve güneş gibi doğal unsurlarla uyumlu bir şekilde konumlandırılabilirler.
- Kapsül evlerin çevresinde kullanılan bitkiler, bulunduğu bölgenin ekosistemine uygun olmalıdır.
- Yerel bitki türleri kullanılarak hem ekolojik denge korunur hem de bakım maliyetleri düşer.

6. Çevresel Etkiyi Azaltma:

- Geleneksel yapılaşmaya kıyasla doğaya daha az zarar verirler.
- Hafif yapıları sayesinde arazinin doğal dokusuna zarar vermeden kurulabilirler.

7. Taşınabilirlik ve Modülerlik:

- Peyzaj düzenlemelerinde kapsül evler, taşınabilir özellikleriyle mevsimsel veya geçici konaklama alanları için idealdir.
- Modüler yapıları sayesinde farklı iklim koşullarına ve arazilere kolayca uyum sağlayabilirler.

8.Turizm ve Ekolojik Konaklama:

- Kamp alanları, dağlık bölgeler, göl kenarları veya doğal parklar gibi turistik alanlarda çevre dostu bir konaklama çözümü sunarlar (Şekil 1).
- Ekoturizm konseptiyle doğa severler için konforlu ama çevreye duyarlı yaşam alanları oluştururlar.



Şekil 1. Kapsül evlerle Doğal alanlarda kamp alanı örneği

9.Tarım ve Doğal Yaşam Alanları ile Entegrasyon:

- Kapsül evler, tarım arazileri veya doğal yaşam alanları içinde küçük ölçekli ekolojik yerleşim alanları oluşturmak için kullanılabilir (Şekil 2).
- Kendi kendine yetebilen bir ekosistem kurarak permakültür ve dikey bahçelerle entegre edilebilirler.



Şekil 2. Küçük ölçekli ekolojik yerleşim alanları

Dünyada artan nüfus imar alanlarının artışını hızlandırmaktadır. Bu durum tarım alanlarını oluşturan verimli toprakları tehdit etmektedir. Gelecektede nüfus bu şekilde artış gösterirse küçük alanlarda daha fazla yerleşim alanlarına ihtiyaç duyulması kaçınılmazdır. Bu nedenle, ekolojik küçük yaşam mekanlarına ihtiyacımız çok fazla olacaktır. Kapsül evlerin tercihler arasında kullanılması gerekebilir. Kapsül evlerin gelecekte tercih edilme nedenleri şu şekilde sıralanabilir:

Düşük Karbon Ayak İzi

Kapsül evlerinin yapımında kullanılan inşaat malzemelerinin azalması ile;

- Geleneksel evlerin inşası büyük miktarda beton, çelik ve ahşap gerektirirken, kapsül evler hafif ve modüler olarak üretildiği için daha az malzeme tüketir.
- Önceden üretilmiş (prefabrik) bileşenler, sahada inşaat atıklarını azaltarak çevreyi korur.

Isı Yalıtımı ve Enerji Verimliliği

1. **Yüksek Verimli Yalıtım Malzemeleri:**

- Kapsül evlerin içi yoğun yalıtımlı malzemelerle kaplandığı için ısı kaybı minimum seviyeye indirilir.
- Pasif ev standartlarına yakın bir enerji verimliliği sunarak kışın ısıtma, yazın soğutma ihtiyacını azaltır**.**

2. Doğal Havalandırma ile Klima Kullanımının Azaltılması:

- Akıllı hava akışı tasarımı sayesinde klima ve yapay havalandırma ihtiyacını en aza indirir**.**
- Kapsül evlerin çevresine yerel bitkiler dikilerek doğal yaşam korunur (Şekil 3)**.**
- Arılar ve kelebekler için doğal yaşam alanları oluşturularak ekosistemin devamlılığına katkı sağlanır.

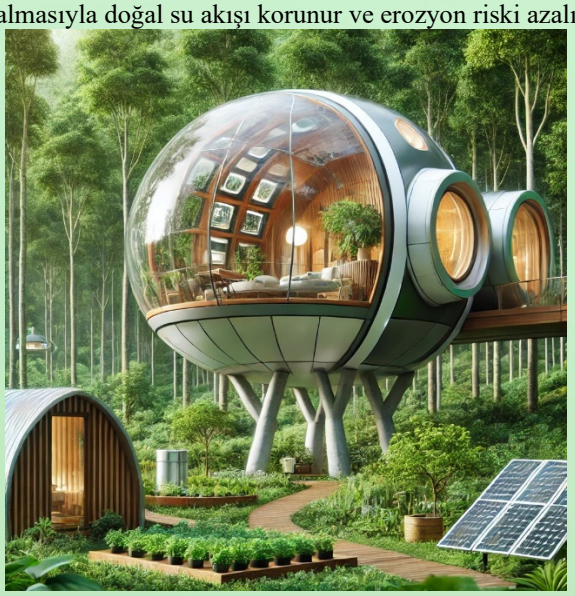


Şekil 3. Kapsül evlerin tasarımında doğal bitki kullanımı

Toprağa Minimum Müdahale

1. **Hafif ve Taşınabilir Yapılar ile Doğanın Korunması:**

- Temelsiz veya hafif temelli inşaat teknikleri kullanılarak toprağa zarar verilmez (Şekil 4).
- Beton kullanımının azalmasıyla doğal su akışı korunur ve erozyon riski azalır**.**



Şekil 5. Temelsiz veya hafif temelli inşaat tekniklerinin kullanımı

2. **Mobilite Sayesinde Sürdürülebilir Alan Kullanımı:**

- Gerektiğinde farklı lokasyonlara taşınabilir, böylece doğa üzerinde kalıcı bir tahribat yaratmaz.
- Özellikle hassas ekosistemlerde geçici ve çevre dostu konaklama çözümleri sunar.

Gelecekte Kapsül Evlerin Kullanım Alanları

Kapsül evler, kompakt, taşınabilir ve sürdürülebilir yapılarıyla gelecekte çok daha yaygın hale gelecek. Artan nüfus, şehirleşme, çevresel sorunlar ve konut maliyetlerinin yükselmesi, bu tür yenilikçi konut çözümlerine olan ihtiyacı artırıyor. Gelecekte kapsül evlerin kullanabileceği alanlar:

1. Şehirleşme ve Yoğun Nüfus Alanlarında Kullanım

- **Metropol Alanlarında Mikro-Yaşam Konseptleri:**

Büyük şehirlerde konut fiyatları yükseldikçe, kapsül evler küçük ölçekli ve uygun maliyetli konut alternatifleri sunabilir.

- **Çatılarda ve Boş Alanlarda Modüler Yerleşimler:**

Yüksek katlı binaların çatılarına ya da kullanılmayan şehir alanlarına kapsül evler yerleştirilerek yeni yaşam alanları oluşturulabilir.

- **Öğrenci ve Bekâr Konutları:**

Üniversitelerin çevresinde uygun fiyatlı ve sürdürülebilir öğrenci konutları olarak kullanılabilir.

2. Afet Bölgelerinde ve Acil Durum Konutları

- **Deprem, Sel ve Doğal Afet Sonrası Barınma:**

Kapsül evler hızlı kurulumları sayesinde acil durumlarda konut ihtiyacını karşılamak için ideal olabilir.

3. Ekoturizm ve Doğa İçinde Yaşam

- **Off-Grid ve Şebekeden Bağımsız Yaşam:**

Güneş panelleri, rüzgar türbinleri ve yağmur suyu toplama sistemleri ile tamamen doğa içinde yaşamak mümkün hale gelecek.

- **Glamping ve Lüks Doğa Otelleri:**

Kapsül evler, modern olanaklarla donatılmış lüks kamp alanlarında tatil konaklaması olarak kullanılabilir.

- **Dağ, Orman ve Deniz Kenarı Yaşamı:**

Doğanın ortasında küçük bir yaşam alanı isteyenler için kapsül evler bireysel kaçış noktaları olabilir.

4. Mars ve Uzayda Kullanım

- **Uzay Keşiflerinde Modüler Yaşam Alanları:**

NASA ve diğer uzay ajansları, Mars ve Ay'da sürdürülebilir yaşam alanları oluşturmak için modüler kapsül ev teknolojilerine yönelebilir.

- **Ekstrem Koşullarda Dayanıklı Yaşam Üniteleri:**

Kapsül evlerin yüksek yalıtımlı yapıları, uzay kolonileri için ideal konut çözümleri sunabilir.

5. Deniz Üzerinde ve Yüzen Şehirlerde Kullanım

- **Yüzen Yaşam Alanları ve Su Üzerinde Konutlar:**

İklim değişikliği nedeniyle deniz seviyesinin yükselmesi, kapsül evlerin deniz üzerinde sürdürülebilir yaşam alanlarına dönüşmesine yol açabilir.

- **Ada ve Göl Üzerinde Özel Konutlar:**

Su kenarındaki bölgelerde, doğayla iç içe minimal yaşam isteyenler için ideal bir çözüm sunar.

6. Geleceğin Çalışma ve Mobil Ofis Alanları

- **Uzaktan Çalışma ve Taşınabilir Ofisler:**

Dijital göçebeler ve uzaktan çalışanlar için doğayla iç içe ofis çözümleri sunabilir.

- **Hareketli İş Alanları ve Mobil Klinikler:**

Sağlık hizmetleri, laboratuvarlar veya taşınabilir ofisler olarak kullanılabilir.

Sonuç

Kapsül evler için peyzaj tasarımı, doğa ile bütünleşik, sürdürülebilir ve fonksiyonellik sağlamaktadır. Kullanılan malzemeler ve bitkiler bölgenin ekosistemine uygun seçilerek doğal doku korunur, bu sayede hem ekolojik denge sağlanır hem de konforlu ve estetik bir yaşam alanı oluşturulmuş olacaktır.

Kapsül evler, gelecekte sürdürülebilir yaşamın, afet yardımlarının, ekoturizmin, uzay keşiflerinin ve mobil yaşam tarzının önemli bir parçasını oluşturacaktır. Hem çevre dostu hem de modüler yapıları sayesinde dünya genelinde çok yönlü kullanım alanları sunacaklardır.

Kapsül evler, yenilenebilir enerji kullanımı, su ve enerji tasarrufu, düşük karbon ayak izi ve doğal ekosistemle uyumlu tasarımı sayesinde çevre dostu bir konut modelidir. Geleneksel konutlara kıyasla daha az enerji tüketerek ve doğaya zarar vermeden sürdürülebilir bir yaşam sunar.

Peyzaj tasarımında kapsül evler, modern yaşamın getirdiği sürdürülebilirlik ihtiyacına yanıt veren, doğayla bütünleşen ve minimalizmi destekleyen yenilikçi çözümler sunmaktadır. Hem bireysel yaşam alanları hem de ekoturizm projeleri için ideal olan bu yapılar, geleceğin çevre dostu konut modelleri arasında önemli bir yer edinmektedir.

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Accessing Drinking Water and Global Warming in Sudan

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Abstract

Sudan's primary water sources are the Nile and non-Nile water resources, including rainfall, seasonal streams, and groundwater, which support a large part of the population. However, water scarcity will worsen with declining rainfall, increasing evaporation, and more frequent extreme weather events due to global warming, affecting rural and urban communities. The climate of Sudan varies from tropical wet and dry in the southwest to desert in the north. From south to north, rainfall drastically declines, and semi-arid regions experience acute water scarcity. In this assessment, we have tried to shed light on the difficulties in guaranteeing sustainable and fair access to drinking water in the face of environmental stressors and offer suggestions for managing Sudan's water resources. To increase agricultural productivity and satisfy the nation's expanding residential and industrial water demands, it is crucial to support the development of water resources for home and agricultural use. Sudan's water resources are multi-sectoral, therefore efficient coordination is essential. Specialized authorities must investigate ways to maximize water usage and set rules to direct and regulate these initiatives.

Key Words: *Global warming, Drinking water, Sudan*

Introduction

A crucial and interrelated component of the Earth's geophysical system, the water cycle affects and reacts to climatic conditions. Earth's radiation balance changes impact cloud dynamics, winds, temperatures, energy, and atmospheric water flow. Temperature changes impact soil moisture and snow-related processes, including melting and snowfall, evaporation and transpiration rates, and cloud characteristics. The occurrence and severity of floods, droughts, and runoff patterns are all impacted by changes in precipitation. These impacts alter plant distribution, growth rates, soil and water conditions, and cloud formation (Tao et al., 2003). Long-term changes in global weather patterns, such as elevated temperatures, modified precipitation, and a rise in extreme weather occurrences, are called climate change. The availability of water resources is one area where these changes significantly impact human civilizations and natural ecosystems (Elsheikh & Nasreldin, 2022).

In sub-Saharan Africa, one of the most urgent issues in urban areas is access to clean drinking water. The situation is worsened by the increasing effects of climate change, especially extreme weather events that alter rainfall patterns and put vulnerable rural and urban households' access to water at even greater risk. Approximately half a billion people worldwide experience severe water scarcity all year, and more than four billion suffer from severe freshwater shortages for at least one month each year (Pörtner et al., 2022). About 2.3 billion people, or 29% of the world's population, did not have access to basic hygiene services, such as water at home, in 2020, according to the WHO/UNICEF-JMP (2021) report. Even though more than 90% of the world's population has access to basic drinking water services (WHO, 2021), sub-Saharan Africa still trails far behind other areas. In rural African villages, piped water is only available to around 5% of the population. By contrast, 54% (about 300 million people) rely on unimproved sources, while 41% rely on improved sources such as wells and boreholes with hand pumps. A major barrier to fulfilling the food and energy needs of the expanding population and accomplishing Sustainable Development Goal 6, which calls for universal access to water, is the pervasiveness of water insecurity (Ayanlade, 2024).

Sudan is Africa's third biggest country, with a landscape that is largely level and has heights between 200 and 600 meters, which is between latitudes 8° and 23° north and longitudes 21° and 39° east, has a "mild desert climate." The northern region experiences the rainy season from July to September for about three months, whereas the southern part experiences it from June to November for about six months. One of the most famous rivers in the world, the Nile flows across Sudan from south to north. At Khartoum, its tributary, the Blue Nile, joins the White Nile. The flow of the Blue Nile is much higher during the rainy season than during the dry season, surpassing the White Nile's normally lower levels (FAO, 2015).

With about half of the Nile River Basin inside its boundaries, Sudan boasts a surface water area of around one million hectares, dominated by a 2,000-kilometer stretch of the Nile and its tributaries. 10% of Sudan is made up of wetlands, while 4% is made up of woods. During the short rainy season, several seasonal watercourses (KHORs)

flow, but their discharge quantities, flow durations, and water quality are not assessed. Perennial rivers beyond the Nile Basin, such as the Khor Abu Habil in Southern Kordofan, the Wadi Azoom, Galol, and other rivers in Darfur, and the Gash, Baraka, and Khor Arbaat rivers in the east, produce an annual discharge of 7.0 BCM (UNEP, 2020). The distribution and availability of water resources in Sudan vary greatly, making management difficult. Climate change worsens This problem, making extreme weather events like droughts and floods more frequent and severe. These difficulties show how urgently the nation needs efficient water resource management plans to guarantee long-term water supply. Thus, we have emphasized in this analysis the challenges of ensuring sustainable and fair access to drinking water in the face of environmental stressors and offered perspectives on managing water resources in Sudan. Improving the development of water resources for household and agricultural use is a top objective to boost agricultural output and satisfy Sudan's expanding need for water for industrial and domestic usage.

Water resources in Sudan

Sudan's primary water resources include surface water sources such as rainfall, rivers, seasonal wadis, Khors, lakes, and wetlands. Groundwater and non-conventional resources like wastewater reuse and desalination are extensively utilized. The country is divided into seven main basins at the watershed level, as depicted in Map 1 (Fanack Water, 2021). Non-Nile water resources play a vital role in Sudan's economy, fulfilling 70% of domestic water needs through rainfall, seasonal streams, wadis, and groundwater. Annual rainfall, averaging 420 billion m^3, has become unreliable since the 1990s, leading to sedimentation and crop failures. Seasonal streams and wadis contribute 2-8 billion m^3 annually but are insufficient for irrigation, while groundwater, recharged at 4 billion m^3 annually, is mainly used for domestic purposes due to its depth. Agriculture, contributing 40% of GDP and employing 80% of the population, relies on rain-fed farming for 90% of cultivated land. Rain-fed agriculture, livestock, and forests collectively contribute over 17% of GDP, support 70% of the population, alleviate poverty, and generate $2.5 billion annually in exports (Bashar, 2019).

Throughout the year, the Nile River and its tributaries provide 73% of Sudan's freshwater supply. With 18.5 billion cubic meters allotted from the Nile's annual supply of 80 billion cubic meters, the 1959 Nile Water Agreement controls Sudan's yearly usage. Most of this water is from the Blue Nile, which rises in Ethiopia and travels through Sudan before entering Egypt. Sudan's Nile system consists of the White Nile, the Atbara River, the Dinder and Rahad rivers, the Blue Nile and its tributaries, and many seasonal streams. There are several seasonal streams in Sudan, which the natives refer to as wadis or khors. The streams usually have a few days of flow from July to October but otherwise stay dry for the rest of the year. The four major streams are shared with neighboring countries: Eritrea shares Gash and Baraka, Chad shares Azum and Hawar, and other streams share South Sudan and the Central African Republic. Other seasonal streams in Sudan include Khor Abu Habil, Wadi El Mugaddam, Wadi Kaja, Wadi Nyala, Alawataib, and Alhawad. The rainfall rate determines the production of most seasonal streams and is not monitored. The average annual flow of the seasonal streams is 5.5 BCM (UNEP, 2020). The annual rainfall in Sudan is estimated at 440 billion cubic meters, with the southern regions receiving the largest amounts, about 800 mm per year. Rainfall decreases northward, with little rainfall between Khartoum and the Egyptian border (120 mm/year). There is a short rainy season with intermittent rainfall in the northern regions. Due to high evapotranspiration rates, rainfall is usually insufficient throughout the year, except for August, September, and October, when runoff helps recharge aquifers and seasonal waterways. However, deforestation exacerbates watershed erosion caused by silt and debris carried by runoff (Omar, 2008). There are also several natural freshwater lakes in Sudan, such as Turdat el-Rahad in Kordofan, Abyad in Southern Kordofan, and Kundi in southern Darfur. Saline lakes may also be found in Sudan, such as Malha in Northern Darfur and the Dariba Crater in Jebel Marra in Western Sudan. With the building of dams, the nation also created artificial reservoirs. These include Merowe in the Northern state, Sennar and Roseires on the Blue Nile, Jebel Aulia on the White Nile, Khashm El-Girba and the Upper Atbara and Setit Complex on the River Atbara, and Lake Nubia in the northernmost section of Sudan, which is a reservoir for the Egyptian High Aswan Dam (UNEP, 2020).

The demands of food security, urbanization, population growth, development, and climate change all put more strain on water resources, making water resources management crucial. Water scarcity is exacerbated by rising demand and pollution, necessitating concerted efforts. The Global Water Partnership defines water resources management as the equitable and sustainable management of land, water, and related resources to preserve ecosystems and optimize economic and social benefits. Fair access to water, effective use, integrated planning, sustainable use, and the development of a fresh approach to water management are among its objectives. According to Bashar (2019), there are still difficulties in establishing sustainable policies and encouraging structural and behavioral reforms for efficient resource use.

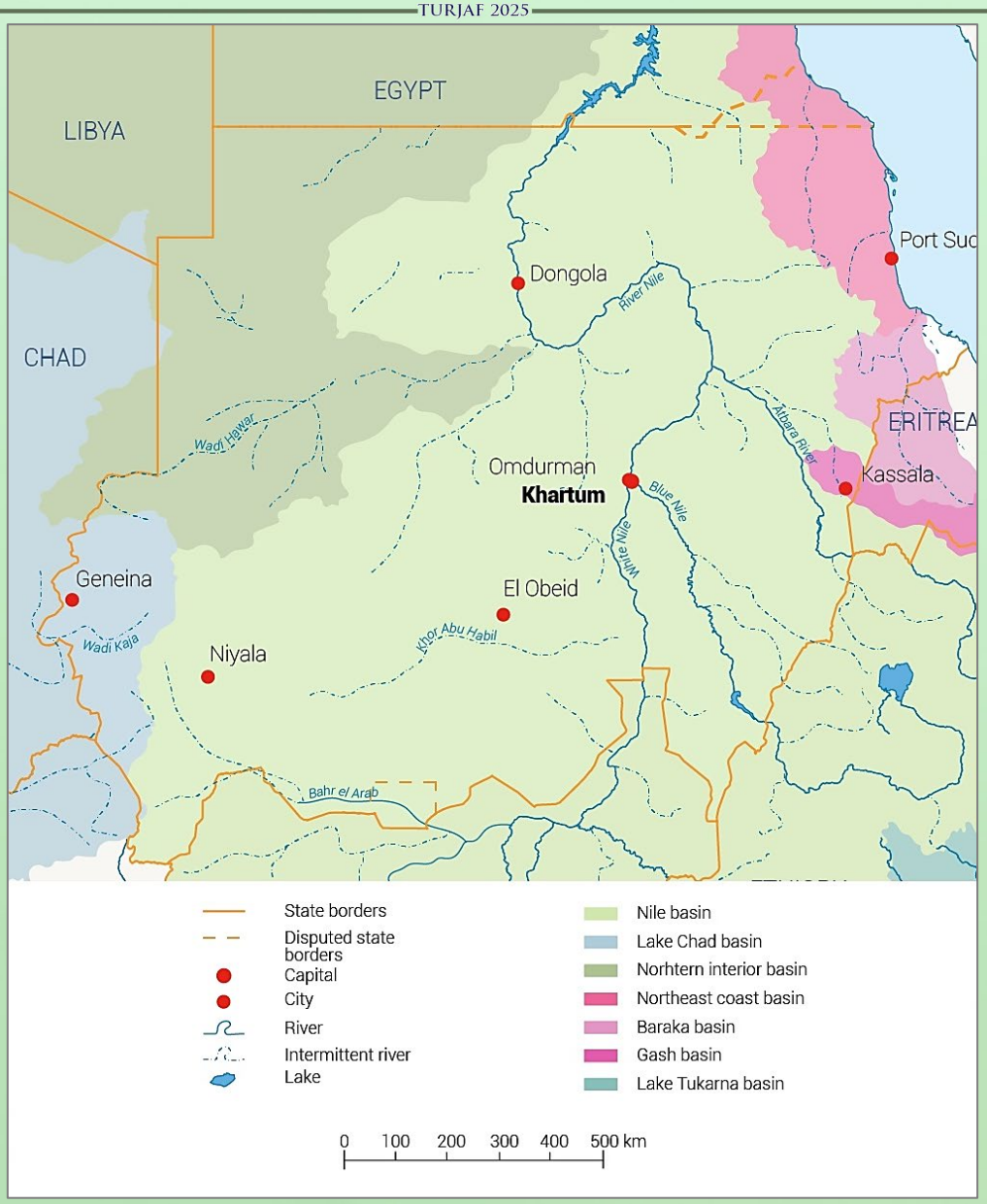


Figure 1. Hydrological basins in Sudan (Fanack Water, 2021).

Accessing Drinking Water and Global Warming in Sudan

Water is an essential and freely available natural resource that sustains life on Earth and plays a crucial role in economic and social development. However, water demand is rising rapidly, particularly in developing nations, due to population growth, urban expansion, industrialization, and agricultural advancements. Irrigation alone accounts for approximately 80% of total water usage, while household consumption is around 10%. As a result, water consumption is increasing at more than twice the rate of population growth, with significant seasonal and annual fluctuations in availability. Additionally, the agricultural sector, historically the largest water consumer, faces growing competition from industrial and domestic demands. This imbalance suggests an impending challenge in ensuring adequate water supply for humans and animals without harming the environment. Moreover, declining water quality is a significant concern, as around 90% of sewage is directly discharged into rivers, lakes, and coastal waters, reducing the availability of clean water. A thorough and organized approach is necessary to overcome these obstacles, enhance water management, and control its usage in developing nations (Omer, 2008). The water cycle, a complex and interdependent component of the Earth's geophysical system, is greatly influenced by climate conditions. Key elements, including wind patterns, temperatures, atmospheric energy distribution, and the movement of clouds and water, are all impacted by changes in the planet's radiation balance (Bağdatli & Arslan, 2019). When freshwater demand in a given area exceeds supply, water scarcity results. Numerous causes, such as population expansion, climate change, and ineffective management of water resources, may contribute to this shortfall (WHO, 2019).

Sudan's water demands are not limited to agriculture; they also include hydropower production, trade, transportation, healthcare, environmental requirements, and industry, mostly agro-based. Despite having a low population density—13 persons per square kilometer on average—more than half of Sudan's population lives on 15% of its territory, mainly in the vicinity of the Nile. 94% of the nation's extracted water is utilized for agriculture, 5% for human and animal usage, and 1% for industry and other uses (Omer, 2008). Reports indicate that Sudan may utilize up to 26 km³ of surface water annually, including its allocated share from the Nile, which is limited to 18.5 km³ per year at Aswan in southern Egypt—equivalent to 20.5 km³ within Sudan before accounting for evaporation and seepage losses—under the 1959 Nile Water Agreement. Additionally, Sudan benefits from 5.5 km³ of water from non-Nile streams. The country heavily depends on the Nile for transportation, agriculture, drinking water, electricity, and recreational activities. Other essential water sources include groundwater reserves and seasonal streams, serving humans and animals (UNEP, 2020). Given the expected impacts of climate change, Sudan must also prepare for increased climate variability and more frequent extreme weather events. Key adaptation strategies include developing policies to mitigate climate change effects, addressing water scarcity through water harvesting, optimizing seasonal streams and rainfall outside the Nile Basin, utilizing groundwater, and cultivating drought-resistant crops. Efficient water management, particularly in irrigated agriculture, is critical to maximizing available resources (Siddig et al., 2020). Water scarcity in Sudan is primarily driven by declining rainfall and rising evaporation rates, threatening food security, rural livelihoods, and public health ((Elsheikh & Nasreldin, 2022). As climate change continues to impact nations worldwide, urgent measures must be taken to minimize its consequences (Bağdatli &Arslan, 2019). Due to the constantly evolving nature of the water industry and fluctuating supply-demand dynamics, Sudan's water policy has changed over time. Limitations like seasonal streams' the Nile's limited storage capacity, and the high expense of pumping groundwater provide serious difficulties on the supply side. Further dam construction is still necessary, especially for harvesting water from seasonal streams, even if the environmental effects of projects must be carefully monitored. Technological developments may enhance the economic feasibility of groundwater monitoring, abstraction, and unconventional water supplies in the future (Omer, 2008). Despite ongoing efforts, millions of Sudanese lack access to clean drinking water. Climate change, inadequate infrastructure, and geopolitical tensions are making water shortages and access to clean and dependable water supplies worse. Regional collaboration, better infrastructure, and sustainable policies are needed to address these issues.

Conclusion

Sudan is facing severe water problems due to climate change-related variables, including rising temperatures and decreasing rainfall. Even though it has a variety of water sources, the amount of water is diminished by siltation, erosion, pollution, and unpredictable rain. To address these issues, Sudan may require costly water projects like dams and desalination plants. Reducing water use, enhancing infrastructure, and using cutting-edge technology are all successful tactics. An ecosystem-based strategy and sustainable management techniques are essential for long-term water security. The Competent authorities should investigate ways to enhance water utilization and create rules to direct and regulate these initiatives. Effective monitoring and adaptation would also be ensured by institutionalizing policy implementation through a robust inspection and audit mechanism. By incorporating sustainable development ideas into laws, Sudan might lessen the effects of climate change and guarantee future water supplies.

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Phytochemical Screening And Inhibitory Activities Of Synthesised Silver Nanoparticles From *Citrus Sinensis* Peel Against Some Selected Pathogens

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Abstract

The increasing resistance of microorganisms to conventional antibiotics necessitates the development of novel antimicrobial agents. Silver nanoparticles (AgNPs) have emerged as an alternative due to their unique properties, such as high surface area to volume ratio and ability to disrupt microbial membranes. This study aims at investigating the phytochemical components, synthesising silver nanoparticles using *Citrus sinensis* peel extract, characterizing, and evaluating their inhibitory activities against some test organisms. *Citrus sinensis* peel extract was used to reduce silver nitrate to AgNPs. Phytochemical analysis was done using standard procedures. UV-Visible spectrophotometry, scanning electron microscopy (SEM), transmission electron microscopy (TEM), Fourier Transform Infared (FTIR), energy-dispersive X-ray spectroscopy (EDX) and X-ray Diffraction (XRD) were used to characterise the AgNPs. The antimicrobial activity was assessed using the agar well diffusion method. Phytochemical analysis revealed that saponins, tannins, flavonoids, alkaloids and phenols were present. Alkaloids (1400 mg/100g) and flavonoids (710 mg/100g) Silver nanoparticles were synthesised and a change in colour from yellow to brown was observed, surface plasmon resonance peak was at 300 nm, the morphology of the AgNPs was spherical, cubical having size ranging from 50 - 150 nm. In the FTIR analysis, the peak at 3466.00 cm^{-1} indicates Hydroxyl groups, 1820.00 cm^{-1} is imine and 1042.00 cm^{-1} is carbonyl and are responsible for the synthesis of AgNPs. XRD analysis confirmed the formation of crystalline nanoparticles. EDX confirmed the presence of silver element. The synthesised AgNPs exhibited significant inhibitory activity against *E. coli* (15±0.32 mm), *K. pnuemonieae* (17±0.45 mm) and *Candida albican* (18±0.24 mm). The green synthesis of silver nanoparticles using *Citrus sinensis* peel extract is an eco-friendly method that utilizes natural properties of plants compounds which has inhibitory potential.

Keywords: *Citrus sinensis peel extract, Silver nanoparticles, Antimicrobial activities, Phytochemical components, Green synthesis*

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Biyolojik Mücadele Uygulanan Biber Seralarında Farklı Tonlardaki Sarı ve Mavi Yapışkan Tuzaklarda *Orius laevigatus* ve *Creontiades Pallidus*'un Yakalanma Durumunun Belirlenmesi

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Özet

Ticari olarak temin edilebilen faydalı organizmaların uygulanması, örtüaltı biber üretiminde zararlı türlerin biyolojik kontrolünde önemli başarılar sağlamıştır. Bunlar arasında, *Orius laevigatus* Fieber, serada yetiştirilen biberlerde önemli bir zararlı olan *Frankliniella occidentalis* (Pergande) popülasyonlarını bastırmak için entegre zararlı yönetimi (IPM) programlarında yaygın olarak kullanılmaktadır. Biyolojik ajanlara ek olarak, biber seralarında yaygın olarak sarı ve mavi yapışkan tuzaklar kullanılmakta olup, öncelikli olarak thrips ve beyazsinekleri hedef almaktadır. Ancak, bu renk tuzakları, *O. laevigatus* gibi faydalı böcekler de dahil olmak üzere hedef olmayan organizmaları istemeden yakalayabilir. Bu çalışmada biyolojik mücadele uygulanan biber seralarında zararlı türler için kullanılan farklı tonlardaki sarı ve mavi yapışkan tuzaklarda yararlı tür *O. laevigatus*'un ve özellikle biyolojik mücadele uygulanan seralarda meyvelerde önemli zararlar oluşturabilen zararlı tür *Creontiades pallidus* (Rambur)'un yakalanma durumu araştırılmıştır. Araştırma, 2022 ve 2023 yetiştirme sezonlarında Antalya ilinde bulunan iki ticari biber serasında yürütülmüştür. Toplam altı tuzak renk çeşidi (her biri üç farklı sarı ve mavi tonlarında) bitkilerin üzerine dikey olarak asılmış, haftalık olarak değiştirilmiş ve her bir tuzakta yakalanan birey sayısı kaydedilmiştir. Denemeler tesadüf blokları deneme desenine göre dört tekerrürlü olarak gerçekleştirilmiş ve her hafta toplam 24 adet tuzak kullanılmıştır. Çalışma sonucuna göre tuzak renk tonlarının *O. laevigatus* üzerindeki etkisi istatistiksel olarak anlamlı bulunurken ($P<0,01$), *C. pallidus* üzerindeki etkisi istatistiksel olarak anlamlı olmamıştır. Her iki yıla ait verilere göre, en fazla *O. laevigatus* bireyi açık mavi tuzaklarda kaydedilmiştir. Buna göre biyolojik mücadele uygulanan seralarda zararlılar için kullanılacak yapışkan tuzakların bu renk tonunda seçilmemesi, faydalı türlerin istenmeyen kayıplarının önlemesi için uygun olabilecektir. Ayrıca mavi tuzaklarda yakalanan tripsler ile sarı tuzaklarda yakalanan beyazsineklerin analizinde, her bir rengin farklı tonları arasında yakalanan birey sayılarında istatistiksel olarak anlamlı bir fark olmadığı da ortaya konulmuştur.

Anahtar Kelimeler: *Orius laevigatus, Creontiades pallidus, yapışkan tuzak, biber, sera*

Assessment of the Capture Status of *Orius laevigatus* and *Creontiades pallidus* on Yellow and Blue Sticky Traps with Varying Hues in Biologically Managed Pepper Greenhouses

Abstract

The application of commercially available beneficial organisms has yielded significant success in the biological control of pest species in greenhouse pepper cultivation. Among these, *Orius laevigatus* Fieber is widely utilized within integrated pest management (IPM) programs to suppress populations of *Frankliniella occidentalis* (Pergande), a major pest in greenhouse-grown peppers. In addition to biological agents, yellow and blue sticky traps are commonly employed in pepper greenhouses, primarily targeting thrips and whiteflies. However, these color-based traps can inadvertently capture non-target organisms, including beneficial predatory insects such as *O. laevigatus*. This study aimed to assess the capture status of *O. laevigatus* and the pest species *Creontiades pallidus* (Rambur) which can cause substantial fruit damage, particularly in greenhouses relying on biological control on sticky traps of varying hues of yellow and blue. The research was conducted in two commercial pepper greenhouses located in Antalya Province during the 2022 and 2023 growing seasons. A total of six trap color variants—three distinct hues each of yellow and blue—were deployed vertically on plants, replaced weekly and the number of individuals captured on each trap was recorded. The experiment followed a randomized complete block design with four replications, employing 24 traps per week. Statistical analysis revealed a significant effect of trap hue on *O. laevigatus* captures ($P < 0.01$), whereas no statistically significant effect was observed for *C. pallidus*. According to data from both years, the highest number of *O. laevigatus* individuals was recorded on light blue traps. These findings suggest that the use of light blue sticky traps should be avoided in biologically managed greenhouses to prevent unintended losses of beneficial predator populations. Moreover, analysis of thrips captured on blue traps and whiteflies on yellow traps indicated that there were no statistically significant differences in the number of individuals captured among the different hues of each color.

Key Words: *Orius laevigatus, Creontiades pallidus, sticky trap, pepper, greenhouse*

ID: 508

The Use Of Installation Art In Landscape Desıgns Of Urban Areas

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Abstract

One of the fundamental characteristics of the nature of visual arts is the deep presence of an aesthetic dimension; this feature makes visual arts unique. However, they not only carry aesthetic value but also possess functional qualities, thus becoming a discipline with striking potential by combining beauty and functionality. In this context, the field of visual arts encompasses both functional and aesthetic features and contributes significantly to the visual appeal of public spaces. Standard design practices often reduce the effectiveness of a space. Therefore, it is necessary to continuously integrate new approaches into design efforts. One such approach is the use of installation art.

As a result, this study aims to increase awareness and appreciation for landscape design practices. In this regard, it is recommended that governments and local communities commission works from artists by considering their emotional and therapeutic effects, which enrich public spaces. Furthermore, artists should be encouraged to produce larger-scale works that serve as monumental structures and enhance the aesthetic experience of the public environment.

The purpose of this study is to identify the areas of use for installation applications in landscape design, to present visual examples, and to develop recommendations.

Key Words: *Installation Art, Niğde, Landscape Architecture, Urban Design, Public Art*

Kent Alanlarının Peyzaj Tasarımlarında Enstalasyon Sanat Kullanımı

Özet

Görsel sanatların doğasının temel niteliklerinden birisi, estetik boyutun derin bir şekilde yer almasıdır; bu özellik, görsel sanatları benzersiz kılmaktadır. Bununla birlikte, sadece estetik bir değer taşımakla kalmayıp işlevsel niteliklere de sahiptir; yani, hem güzelliği hem de işlevselliği bir araya getirerek dikkat çekici bir potansiyele sahip bir disiplin hâline gelmektedir. Bu bağlamda, görsel sanatlar alanı hem işlevsel hem de estetik özellikleri bünyesinde barındırır ve tasarım alanlarının görsel çekiciliğine önemli katkılar sunar. Standart tasarım uygulamaları alanın etkililik derecesini düşürmektedir. Bu nedenle, tasarım çalışmalarına sürekli yeni uygulamalar eklemek gerekmektedir. Bunlardan birisi enstalasyon çalışmasıdır.

Sonuç olarak bu araştırma, peyzaj tasarım çalışmalarına yönelik farkındalığı ve takdiri artırmayı hedeflemektedir. Bu nedenle, hükümetlerin ve yerel toplulukların, kamusal alanları zenginleştiren, duygusal ve terapötik etkileri de göz önünde bulundurarak sanatçılardan eserler sipariş etmeleri önerilmektedir. Ayrıca sanatçılar, hem anıtsal yapılar olarak hizmet edecek hem de kamusal çevrenin estetik deneyimini artıracak daha büyük ölçekli eserler üretmeleri konusunda teşvik edilmesi amaçlanmaktadır. Aynı zamanda, enstalasyon uygulamalarının peyzaj tasarım çalışmalarında kullanım alanlarını belirlemek, çizim örnekleri sunmak ve öneriler geliştirmektir.

Anahtar Kelimeler: *Enstalasyon, Niğde, Peyzaj Mimarlığı, Tasarım, Sanat*

Giriş

Enstalasyon sanatı, postmodern felsefe ve estetiğin etkisi altında ortaya çıkan yeni bir sanat kategorisi olan çağdaş bir sanat türüdür. Enstalasyon sanatı, insanların yaşam deneyimlerinin bir uzantısıdır ve izleyicinin katılımı, enstalasyon sanatının ayrılmaz bir parçasıdır. Enstalasyon sanatı yaratım ortamı, izleyiciyi belirlenmiş bir mekânda pasif izleyicilikten aktif hissetme durumuna dönüştürür. Bu süreçte yalnızca zihinsel düşünme ve bedensel müdahale değil, aynı zamanda görme, işitme, dokunma, koku alma ve tat alma duyuları da kullanılır.

Enstalasyon sanatının en önemli özelliklerinden biri, gündelik hayatın olağan akışını bozmasıdır. Bu tür bir yer değiştirme sonucunda izleyici, eseri kolayca kabul etmek yerine çok boyutlu bir anlamlandırma sürecine girmek zorunda kalır. Kullanılan malzemeler çoğunlukla günlük nesneler ve endüstriyel ürünlerden oluşur. Zemine yerleştirilen heykeller gibi unsurlar nedeniyle, geleneksel çerçeve sanatlarından ayrılır ve izleyicinin eseri farklı açılardan değerlendirmesini, çeşitli çağrışımlar yapmasını ve hatta eserin sergilendiği ortamla ilişkisini sorgulamasını ister.

Enstalasyon sanatı herhangi bir türle sınırlandırılmaz ve resim, dokunsal modeller, mimari, müzik, tiyatro, şiir, deneme, sinema, televizyon, ses, video ve fotoğraf gibi çeşitli sanat dallarını özgürce bir arada kullanabilir (Liang, 2007). Enstalasyon sanatı, basitçe ifade edilirse, "mekân + malzeme + duygu" bileşiminden oluşan bir sanat biçimidir.

Günümüzde, insanlar kentsel tasarıma giderek daha fazla önem vermekte ve sanatsal beğenileri giderek yükselmektedir. İyi bir kentsel alan tasarımı, insanların bu alanlara olan ilgisini artırırken, ekonomik gelişime de büyük katkı sağlamaktadır. Kentin manevi kültürünü temsil eden unsurlar olarak görülebilir ve bu alanlardaki enstalasyon sanatının tasarımı, kamusal alanın bireyselliğini, sanatsal yönünü ve kompozisyonunu doğrudan etkilemektedir.

Bu nedenle, insanların kentlerde beklentilerini karşılamak ve şehrin manevi gelişimiyle uyum sağlamak adına, kentsel alanlarında enstalasyon sanatının tasarımını incelemek büyük bir pratik öneme sahiptir. Kentsel alanlardaki sanat tasarımları, sadece şehrin sanat anlayışını yansıtmakla kalmaz, aynı zamanda kentsel alan tasarımına dair düşünce yapısını da ortaya koyar ve en önemlisi, halkın şehrin ruhuna yönelik ihtiyaçlarını karşılamayı amaçlar.

İnsanların manevi dünyaya yönelik artan beklentileriyle birlikte, sanat tasarımının içeriği günlük yaşamın her alanında görülmektedir. Kentsel kamusal alanlar, yalnızca bir şehrin kültürünü temsil etmekle kalmaz, aynı zamanda insanların kente ruhsal bakış açısını da yansıtır. Bu nedenle, kentsel alanlarda dekoratif sanat tasarımının uygulanması, şehrin dikkatini sürekli olarak artıracak ve farklı yenilikçi tasarım fikirlerinin şehir içinde hayata geçirilmesine olanak tanıyacaktır .

Günümüzde, enstalasyon sanatının kentsel alanlarda uygulanması, toplumsal gelişimin kaçınılmaz bir trendi haline gelmektedir. Bu yalnızca yüksek bir uygulanabilirliğe sahip olmakla kalmaz, aynı zamanda yerel ekonomik kalkınmayı da teşvik etme konusunda önemli bir rol oynar.

Kentsel alanların peyzaj enstalasyon sanatı tasarımı, sanatın kapsayıcılığını ve açıklığını gösteren bir olgudur. Bu anlayış, enstalasyon sanatının tasarımında hem ön koşul hem de temel oluşturur. Bu tasarım sadece sanat formunun yeniliğini değil, aynı zamanda şehir sakinlerinin estetik algısını ve estetik gelişimini de içerir.

Kentsel alanların kendine özgü bir sürdürülebilirliği vardır ve insanların günlük yaşamlarında dinlenmek için tercih ettikleri yerler arasında bulunur. Bu nedenle, kentsel alanlarda yapılan enstalasyon sanatı tasarımları, doğrudan şehir sakinlerinin mutluluğunu etkileyebilir. Sanatın farklı ifade biçimleri vardır ve her kentin kendine özgü sanatsal biçimlerini sergiler.

Dekoratif sanat tasarımı, kentsel alanlara ruh katar; bu da şehrin genel yapısını ve kent sakinlerinin estetik anlayış seviyesini yansıtır. Günümüzde insanların sanatsal beğenisi giderek daha fazla çeşitlilik gösterse de enstalasyon sanatının işlevi kanıtlanmış olup, toplum tarafından kolayca kabul edilebilir bir hale gelmiştir. Böylece, instalasyon sanatı zamanla kent estetiğinin önemli bir temsilcisi olma yolunda ilerlemektedir.

Toplumun gelişmesi ve zamanın değişmesiyle birlikte geleneksel estetik anlayışı da sürekli dönüşmektedir. Kentsel alanlarla enstalasyon sanatının bütünleşmesi, bu güzelliği somutlaştırarak kent medeniyetinin gelişimini teşvik edecek ve topluma farklı yaşam deneyimleri sunacaktır.

Kentsel alan tasarımı ve enstalasyon sanatı, her ikisi de sanatın birer biçimi olup, hatta belirli benzerlikler taşımaktadır. Bu durum analiz edildiğinde, iki unsurun birbirine entegre olmasında büyük bir direnç olmadığı görülebilir.

Günümüzde ülkemizin gelişimi nispeten istikrarlı bir seyir izlemekte, sosyal ekonomi de ilerlemekte ve toplum sanata geniş bir hoşgörü ile yaklaşmaktadır. Bu olumlu sosyal ortam, sanat tasarımına daha geniş bir yaşam alanı sunarak, kültürel çeşitliliğin ve kültürel kapsayıcılığın bir göstergesi haline gelmiştir.

Kentsel alan enstalasyon sanatının tasarımı, bir şehrin sembolü olmasının yanı sıra, aynı zamanda kentin ruhsal perspektifinin de bir yansımasıdır. Şehir gelişim sürecinde vazgeçilmez ve önemli unsurlardan biridir. Enstalasyon sanatı bir sanat ifade biçimi olarak ele alındığında, kent gelişiminin özelliklerini yansıtan tasarım içeriklerine odaklanabilir. Aynı zamanda, bu sanat biçimi, kentsel ekonomik ve kültürel gelişimi teşvik eden temel itici güçlerden biri olarak da öne çıkmaktadır.

İnteraktif sanat ve çevresel tasarımın kesişim noktası olarak kabul edilen instalasyon sanatı, peyzaj tasarımında salutojenik etkiler yaratma potansiyeline sahiptir. Salutojenik tasarım, bireylerin sağlığını ve refahını destekleyen mekânlar oluşturmayı amaçlayan bir yaklaşımdır. Bu bağlamda, instalasyon sanatı aşağıdaki yollarla peyzaj tasarımında salutojenik etkiler yaratabilir:

Enstalasyon Sanatına Salutojenik Etki

Salutojenik yaklaşım, kişilerin/toplumların fiziksel ve zihinsel yönden sağlıklı olmalarını teşvik ederken hastalığın kaynakları yerine sağlığın kökenlerine odaklanan bir modeldir (Karaca, 2018). Bu yaklaşım mimari tasarımlarda uygulama alanı bulmaktadır. Salutojenik tasarımda mekanın insanlar üzerinde yarattığı olumsuz etkiyi en az seviyeye indirgemenin yanısıra diğer yandan bozulmuş sağlığın tedavi edilmesi açısından da kritik bir rol oynamaktadır (Özgön, 2022). Bu çerçevede toplum ruh sağlığı merkezlerde yapılan uygulamalar büyük önem arz etmektedir. Örneğin, bitki terapi bahçeleri hastaların ihtiyaç, istek ve becerilerine uygun olarak tasarlandığında tedavi sürecine olumlu etki eden uygulamalardan birisi olmuştur (Satıl & Aktaş, 2021). Bir başka deyişle, mekansal örüntü içerisinde öznenin eyleyici kılınmasının tedavi üzerine olumlu etkileri görülmektedir.

Bu süreci, katılımın odak olduğu, mekan ile birlikteliğin sağlandığı bir sanat türü olan enstalasyon uygulamaları destekleyecektir. "Enstalasyon sanatı, tıpkı mimarlık, bilim ve teknolojide olduğu gibi, peyzaj mimarlığı alanına dahil edilmiştir." (Durdymyradov & Ak Erken, 2023). Enstalasyon, kullanımına el verdiği farklı materyaller açısından çeşitli peyzaj unsurlarının da değerlendirilebileceği bir sanat türü olarak da yorumlanabilir. Bu bağlamda, salutojenik mimari uygulanarak tasarlanmış toplum sağlığı merkezlerinde tedavi gören hastalara, peyzaj materyalleri ile enstalasyon sanatı uygulama alanları sunulması planlanmaktadır. Hastaların üreteceği ya da parçası olacakları sanat eserlerinin belirli aralıklarla sergilenmesi sağlanarak toplumsal entegrasyon ve farkındalığın geliştirilmesi hedeflenmektedir.

1. Duyusal ve Estetik Uyarım

Sanat enstalasyonları, doğayla etkileşim içinde olan renkler, formlar, ışık oyunları ve malzeme kullanımlarıyla psikolojik rahatlama sağlayabilir**.** Doğayla bütünleşen sanat eserleri, stres seviyelerini düşürerek dinginlik ve huzur hissi yaratır (Şekil 1)**.**



Şekil 1. Doğayla bütünleşen sanat eserleri (Sağ resim (Anonim, 2021)).

2. Katılımcı ve Etkileşimli Mekânlar

Özellikle kentsel peyzajlarda konumlandırılan sanat enstalasyonları, bireylerin mekânla etkileşime girmesine ve fiziksel aktiviteyi teşvik etmesine olanak tanır. Örneğin, dokunulabilir yüzeyler, akustik deneyimler veya hareketle değişen sanat eserleri**,** bireylerin çevreyle bağ kurmasını sağlar (Şekil 2).



Şekil 2. Hareketle değişen sanat eserleri

3. Doğa ile Bağlantıyı Güçlendirme

Biyofilik tasarım ilkeleriyle harmanlanan sanat enstalasyonları, insanların doğayla duygusal bağ kurmasına yardımcı olabilir. Örneğin**,** su öğeleriyle bütünleşen sanat eserleri**,** meditasyon alanları veya doğadan ilham alan formlar, bireylerde zihinsel rahatlama ve yenilenme hissi yaratır (Şekil 3)**.**



Şekil 3. Doğadan ilham alma sanatı (Anonim, 2020).

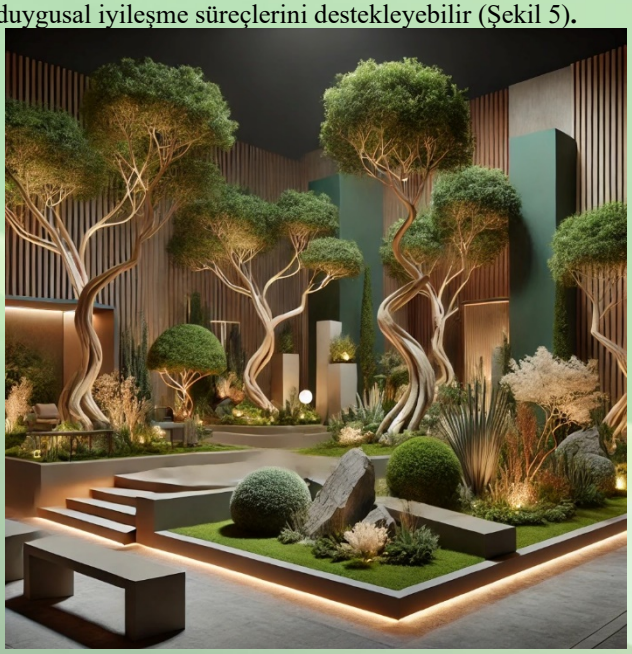
Doğal unsurlardan yararlanarak yapılan tasarımlar insanlar üzerinde görsel etkililik yaratmaktadır. Bitkiler, su öğeleri, doğal ışık kullanımı vb. öğeler doğayı yansıtmaktadır (Şekil 4).



Şekil 4. İnstalasyon tasarımında bitki kullanımı (Anonim, 2020).

4. Duygusal İyileşme ve Anlamlı Deneyimler

Sanat, bireylerin kendilerini ifade etmelerine, anılarını canlandırmalarına ve topluluklarla bağ kurmalarına yardımcı olabilir. Özellikle hastane bahçeleri, terapi bahçeleri veya kentsel alanlarda yer alan anlam yüklü enstalasyonlar, bireylerin duygusal iyileşme süreçlerini destekleyebilir (Şekil 5).



Şekil 5. Kentsel alanlarda yer alan anlam yüklü enstalasyonlar

5. Mekânsal Algıyı ve Harekete Geçirici Gücü Artırma

İyi tasarlanmış bir sanat enstalasyonu, insanları belirli bir rotada hareket etmeye teşvik edebilir. Örneğin**,** ışık ve gölge oyunlarıyla yönlendirilmiş yürüyüş yolları, bireyleri mekânın farklı köşelerini keşfetmeye itebilir. Bu durum, peyzajda aktif kullanım ve keşif duygusunu artırabilir (Şekil 6)**.**

Kısacası, instalasyon kullanılarak yapılan salutojenik tasarım, sağlığı ve iyilik halini teşvik eden mekanlar yaratmayı amaçlar. Bir enstalasyon tasarımında bu etkiyi görselleştirmek için doğal unsurlar **(** Bitkiler, su öğeleri, doğal ışık kullanımı), Akışkan formlar (Organik ve yuvarlak hatlı yapılar), duyusal deneyim (Yumuşak dokular, doğal malzemeler, rahatlatıcı renkler), etkileşimli alanlar kullanıcıların zihinsel ve fiziksel olarak aktif olabileceği tasarım ögelerinden yararlanılarak mekanlar oluşturmak kentlerde olumlu etkiler yaratmaktadır.



Şekil 6. Işık ve gölge oyunlarıyla yönlendirilmiş yürüyüş yolları (Anonim, 2021).

Sonuç

Peyzaj tasarımında instalasyon sanatı, estetik deneyimin ötesine geçerek zihinsel rahatlama, fiziksel aktivite, toplumsal bağ ve doğayla etkileşim gibi pek çok salutojenik fayda sağlayabilir. Bu nedenle, sanat ve doğayı birleştiren yenilikçi yaklaşımlar**,** sürdürülebilir ve sağlığı destekleyen kamusal alanlar yaratmada önemli bir rol oynayabilir.

Sanat enstalasyonlarının salutojenik etkisi, bireylerin hem bireysel hem de kolektif düzeyde daha sağlıklı, mutlu ve bağlı hissetmelerine katkıda bulunur. Bu tür tasarımlar, kentlerin ve yaşam alanlarının daha yaşanabilir, sürdürülebilir ve insan merkezli olmasını sağlar**.**

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Determination of Heating Potential with Geothermal Energy in Greenhouses in Kırklareli Province

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Abstract

The most important variable in ensuring production independent of climate conditions in greenhouses is the provision of heating facilities. Especially in conditions where the air temperature is low, the desired temperature must be provided in the greenhouse for optimum plant development. In addition, the high cost of heating facilities has caused greenhouse farming to remain limited in some of our regions. In this respect, the provision of heating facilities provided by natural resources has become important in terms of the regional spread of greenhouse farming. Sustainable and low-cost heating facilities can be used without harming the environment by using natural resources in greenhouses. In this study, the development of heating facilities with geothermal resources in Kırklareli province, where greenhouse farming is not very developed, was investigated. In this context, potential geothermal resources in Kırklareli province were investigated within the scope of the literature and the heating potentials of the obtained geothermal resources were revealed. In the study, the potential for use of the newly found geothermal energy source in the Kırklareli - Asılbeyli region was revealed. Within the scope of this potential, the current status of greenhouse activities in Kırklareli province was determined in terms of heating with geothermal resources. With the research conducted, it can be concluded that greenhouse farming has a development potential with the increase in studies on finding existing geothermal resources in Kırklareli province. In addition, further research on heating greenhouse activities with natural resources in the region will have a positive impact on greenhouse-based production. The results obtained have shown that production in greenhouses using geothermal resources in Kırklareli province will contribute to the development of greenhouse farming in the province.

Key Words: *Greenhouse, Geothermal energy, Greenhouse Air Conditioning, Heating, Kırklareli.*

Introduction

Greenhouses are facilities where suitable environments for plant cultivation are created by controlling the environmental conditions depending on the climate. Creating optimum conditions in the greenhouse is only possible by equipping the greenhouses with systems such as heating, cooling, lighting, ventilation and humidification. Today, cultivation is carried out in automatic and fully controlled greenhouses in countries with cool climate zones such as England and the Netherlands. In countries with temperate climate zones, including our country, greenhouse cultivation has developed depending on ecological conditions (Tüzel et al., 2010).

The most important variable in ensuring production in greenhouses independent of climate conditions is the provision of heating facilities. Especially in conditions with low air temperatures, the desired temperature inside the greenhouse must be provided for optimum plant development. In this respect, temperature is one of the most important elements of the climate to be created inside the greenhouse. It is a known fact that every 10 °C increase in the temperature inside the greenhouse increases plant development approximately two-fold, provided that the other elements that make up the greenhouse climate are also at appropriate values and that the highest temperature allowed for the plant being grown is not exceeded (Yağcıoğlu, 2005).

The desired level of cultivation in greenhouses can be achieved by providing the desired conditions for the plants in the greenhouse. The purpose of heating, which has an important place in greenhouse air conditioning, is to increase yield and quality by successfully using heating systems to create the temperature desired by the plants in the greenhouse during cold times. One of the most important inputs of production in greenhouses is heating. Heating costs constitute 60% of all costs in the greenhouse. (Harzadın, 1994).

In greenhouse heating, some factors should be taken into consideration in terms of plant cultivation. The critical factor in the effectiveness of the heating system is not the air temperature inside the greenhouse, but the leaf and root temperature of the plant. The photosynthetic activity of the plant depends not only on the leaf temperature but

also on the speed and direction of air flow. The heat balance of the plant canopy also depends on the root temperature. It is possible to affect the air temperature by changing the root temperature (Gül et al., 1994).
One of the most important inputs in greenhouse production is heating. Heating costs constitute 60% of all greenhouse costs. Heating is done in very few greenhouses in our country. In most greenhouses, heating is done for a very limited time as a frost protection measure. Not heating greenhouses reduces yield, but it is possible to get products at certain times when the price is not high, hormone use for fertilization is difficult and therefore unhealthy products are produced (Harzadın, 1994).

Heating systems that can be used in greenhouses can be classified under different names. These heating systems are named as stove heating, central heating, hot air heating, heat pump heating, solar energy heating and geothermal energy heating. (Yağcıoğlu, 2005;Günay, 1999).

Among the renewable energy sources, geothermal, which is one of the most important, offers many benefits, like other renewable energy sources, to the energy sector and therefore to the countries. According to one definition, geothermal energy is a type of energy that is formed when the heat formed under the earth's crust heats the underground waters and then this water rises to the surface (Çukurçayır and Sağır, 2008). Geothermal energy is a type of energy that is difficult to consume, provided that it is used correctly. On the other hand, it is easy to detect and produce. It is also low-cost and the investment returns in a short time. It is also less harmful to the environment compared to other sources. Due to all these features, it is preferred not only in electricity production but also in different areas of the industry, in the health sector, in agriculture and tourism sectors, which are different but support each other (Külekçi, 2009).

Our country ranks 1st in Europe and 7th in the world in terms of geothermal energy potential with 31,500 MWt. As of 2004, we have only been able to benefit from 3-3.5% of this potential. Turkey ranks 5th in the world with 992 MWt in terms of direct use applications such as regional heating, greenhouse heating and thermal spring utilization (Dağdaş, 2004).

In the first studies on the use of geothermal resources in greenhouse heating, the use of fluids with a temperature of at least 60 °C was recommended. Later, it was determined that this lower limit was sufficient to be 20 - 25 °C. For example, it is known that projects using geothermal waters with a temperature of 40 °C in Italy, 34 °C in Greece, and 52 °C in Czechoslovakia have yielded quite successful results. In Israel, geothermal waters with a temperature of 30 - 60 °C are used for greenhouse heating in the winter, while some of these resources are also used for irrigation in the summer. In Sivas, it has been shown that greenhouse heating by circulating hot water with a temperature of 46 °C in plastic pipes located above and below the ground is sufficient for plant production (Kasap et al., 1990).

In this study, the development of heating opportunities with geothermal resources in Kırklareli province, where greenhouse farming has not shown much development, has been investigated. In this context, potential geothermal resources in Kırklareli province have been investigated. The heating potentials of the obtained geothermal resources have been revealed. In the study, the potential use of the newly found geothermal energy source in the Kırklareli Asılbeyli region has been revealed. Within the scope of this potential, the potential that can be heated with geothermal resources has been determined within the scope of the literature within the scope of the current situation of greenhouse farming in Kırklareli province. With the research, it can be concluded that greenhouse farming has a development potential with the increase in the studies on finding the existing geothermal resources in Kırklareli province. In addition, conducting more and detailed studies on heating greenhouse farming studies with natural resources in the region will have positive effects on greenhouse-based production. According to the results obtained within the scope of the literature, it has been seen that production in greenhouses by utilizing geothermal resources in Kırklareli province will contribute to the development of greenhouse farming in the province.

Materials and Methods

The research investigated the possibilities of developing heating opportunities with geothermal resources in Kırklareli province, where greenhouse farming has not shown much development. In this context, potential geothermal resources in Kırklareli province were investigated. The geographical location of the research area Kırklareli province is given in Figure 1.

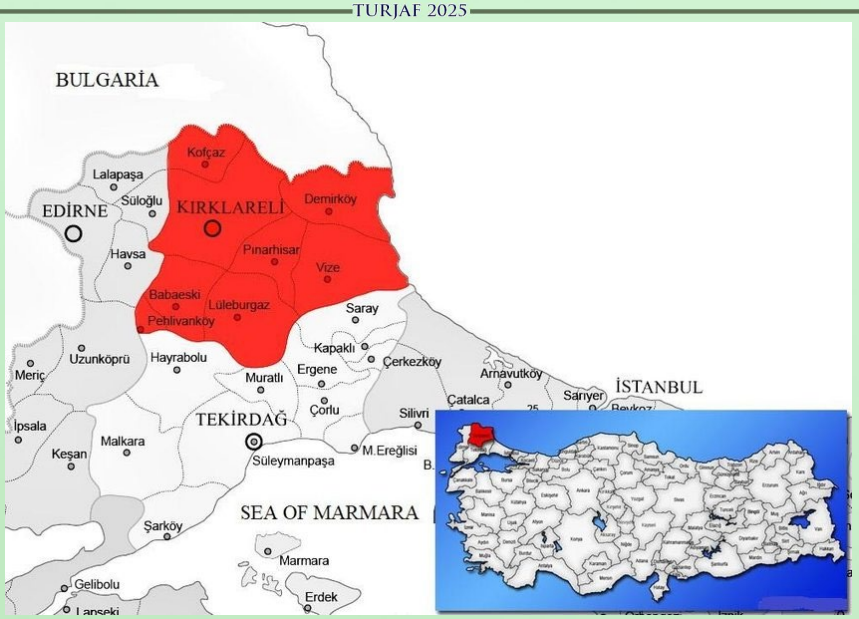


Figure 1. Research area

Kırklareli is located in the Thrace Region of Turkey and the annual average temperature is determined as 13.4 °C. The average sunshine duration is 4.6 hours and the average number of rainy days is determined as 98.6 days. When the maximum temperature values are examined, it is seen that the lowest temperature is -15.6 °C and the highest temperature is 42.5 °C. (MGM, 2025) The climatic values of the region are given in Table 1.

Table 1. Climatic values of Kırklareli province (MGM, 2025)

Kırklarelı/Months	1	2	3	4	5	6	7	8	9	10	11	12	Annual
Average Temperature (°C)	3,0	4,2	6,9	12,1	17,1	21,5	23,9	23,7	19,4	14,1	9,3	5,2	13.4
Average Highest Temperature (°C)	6,9	8,7	12,2	18,0	23,0	28,1	30,7	30,7	26,2	20,0	13,9	8,8	19,0
Average Minimum Temperature (°C)	0,1	1,0	3,0	7,2	11,6	15,6	17,9	17,8	14,1	9,9	5,9	2,4	8.9
Average Sunbathing Time (hours)	2,0	2,6	3,6	4,8	6,4	7,0	7,6	7,6	5,6	4,0	2,7	1,8	4,6
Average Number of Rainy Days	11,05	9,05	9,26	10,33	10,00	8,58	4,71	3,59	4,85	6,91	8,55	11,29	98.2
Highest Temperature (°C)	18,9	23,1	25,7	31,5	36,0	40,4	42,5	40,4	38,8	37,4	28,9	21,6	42.5
Lowest Temperature (°C)	-15,8	-15,0	-11,8	-3,0	1,4	5,8	8,8	8,7	3,0	-3,4	-7,2	-11,1	-15.8

Results and Discussion

When the greenhouse presence of Kırklareli province is examined, it is seen that greenhouses with plastic covers come to the forefront according to the covering material. Although there are no glass greenhouses, when the data of the last 20 years are examined, it is seen that the amount of greenhouses with plastic covering material has increased approximately 20 times. (TÜİK, 2025) The greenhouse amounts of Kırklareli province in the last 20 years are given in Figure 2.

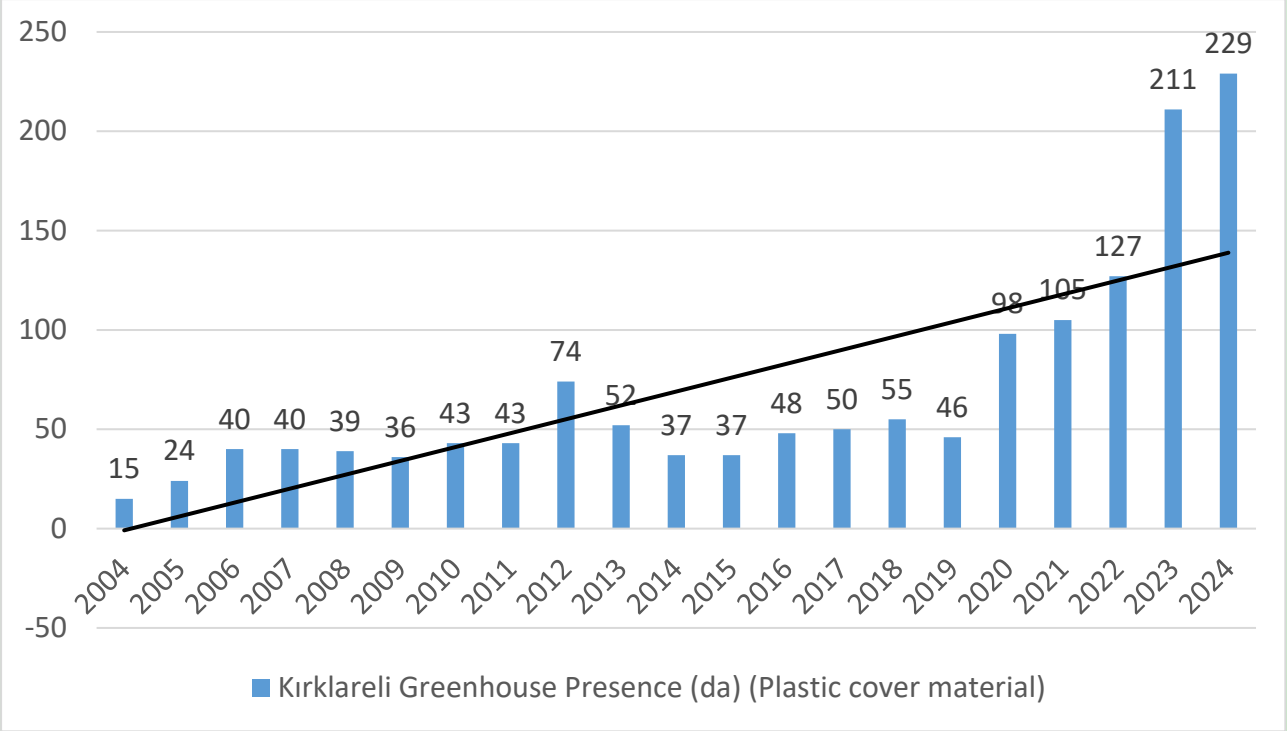


Figure 2. Greenhouse presence in Kırklareli province

Within the scope of the research, in order to determine the geothermal energy capacity in the region, research was conducted from many sources such as the Ministry of Energy and Natural Resources, Mineral Research and Exploration (MTA), Energy institutes and organizations. An existing geothermal energy potential was found in Asilbeyli Village, which is affiliated to the central district of Kırklareli province. (MTA, 2017-a). The people of Asilbeyli, which is 6 km away from the city center, generally work in agricultural areas. The area with potential geothermal energy is given in Figure 3.

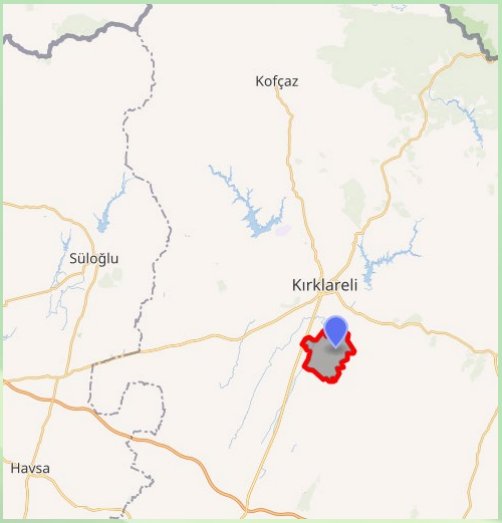


Figure 3. Potential geothermal energy field of Kırklareli province

The depth of the geothermal reservoir in the region is 1500 m. According to well test data, the maximum well static temperature is 74.38 °C at 1476 meters. According to the water loss test, the reservoir level is approximately 1100-1200 meters, which shows that the temperature is between 55 °C and 64 °C. The energy potential of the well is suitable for direct use applications such as home heating, greenhouse farming and thermal tourism. (MTA, 2017-a).

According to the data obtained as a result of the studies carried out in the first stage, the well has an energy potential of 2.38 MWt (MW thermal). Since Kırklareli has an important agricultural production, using this resource in

agricultural production in a reliable and environmentally friendly manner will be one of the best evaluation methods. (MTA, 2017-b).

In terms of using geothermal energy in greenhouse heating, it is aimed to find an optimum value in terms of flow rate with water inlet-outlet and pipe-environment equation combinations. As a result of the studies carried out in this context, greenhouses can be heated in an area of approximately 15 decares according to the thermal energy potential of the well in the region (MTA, 2017-b). This rate is approximately 20% of the plastic greenhouse assets of Kırklareli province. (TÜİK, 2025). This amount may vary with the type of greenhouse, the cover material used in greenhouses, the climatic requirements of the agricultural products to be grown and the detailed determination of the greenhouse heating needs.

Conclusion

Within the scope of the research, it has been seen that it is possible to use geothermal energy in greenhouse heating in Kırklareli province in the light of the literature. According to the current data and initial studies, the geothermal resource in the region can be used in a greenhouse of approximately 15 decares. This amount may vary depending on the product to be grown, the type of greenhouse and the new resources that may be found in the future. This situation may accelerate the development of greenhouse farming in Kırklareli province. The availability of geothermal energy in the region will also increase the use of different renewable energy resources. The use of geothermal energy will positively contribute to the design of greenhouse heating systems that integrate wind and solar energy. It will positively contribute to the development of the region and employment conditions. The decrease in cost with the use of geothermal resources, which is a renewable energy, in greenhouses will be positively reflected in food prices.

As a result, it can be said that the discovery of a new geothermal source in the province of Kırklareli will have a positive effect on the development of greenhouse farming in the region. In this context, considering the potential of finding new geothermal sources in the future, it is recommended to increase the development of geothermal heating systems in greenhouses. Optimum use of geothermal energy according to the plant requirements to be grown in greenhouses, calculation of system capacities and creation of the most appropriate architectural design for the region will accelerate the development of greenhouse farming.

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Yenilebilir Peyzaj Bahçelerinin Üniversite Öğrencileri Üzerindeki Etkileri: Selçuk Üniversitesi Örneği

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Özet

Bu çalışma, Selçuk Üniversitesi kampüsünde oluşturulan yenilebilir peyzaj bahçesinin üniversite öğrencileri üzerindeki etkilerini araştırmayı amaçlamaktadır. Günümüz kentlerinde sosyolojik, ekonomik, ekolojik ve kültürel farkındalıkların artmasıyla birlikte yenilebilir peyzaj kavramı büyük önem kazanmıştır. Bu yaklaşım, kent sakinlerine doğrudan ve sağlıklı gıda sağlama, kentsel biyoçeşitliliği destekleme, topluluklar arası iş birliğini güçlendirme, çevre eğitimi fırsatları yaratma ve sürdürülebilirlik hedeflerine ulaşma gibi çeşitli önemli katkılar sunmaktadır. Çalışmanın temelini oluşturan ilk aşamada, Selçuk Üniversitesi öğrencilerinin yenilebilir peyzaj kavramına dair mevcut bilgi düzeyleri incelenecek ve bu alanların potansiyel faydalarına ilişkin farkındalıkları bir anket çalışması aracılığıyla belirlenecektir. Anketin sonraki bölümlerinde ise bahçeyi aktif olarak kullanan öğrencilere yönelik sorular yöneltilecektir. Bu sorular aracılığıyla öğrencilerin bahçeyi ne sıklıkta ziyaret ettikleri, hangi amaçlarla kullandıkları ve bahçeye yönelik genel memnuniyet düzeyleri gibi önemli veriler toplanarak kullanım sonrası değerlendirmeler yapılacaktır. Elde edilen verilerin analiz edilmesiyle, öğrencilerin yenilebilir peyzaj konusundaki genel bilgi birikimleri ve bilinç düzeyleri ile birlikte kampüs içerisindeki yenilebilir peyzaj bahçesine karşı geliştirdikleri tutumlar ve bahçeyi kullanma alışkanlıkları bütüncül bir şekilde ortaya konulacaktır. Araştırma sonucunda, bir üniversite kampüsünde hayata geçirilen yenilebilir bitkiler bahçesinin öğrencilerin yaşamları üzerindeki çeşitli etkileri değerlendirilecektir. Buna ek olarak, elde edilen bulgular ışığında gelecekte benzer yenilebilir peyzaj uygulamalarının daha başarılı bir şekilde hayata geçirilmesi için somut ve uygulanabilir öneriler sunulması temel hedeflerden biridir.

Anahtar Kelimeler: *Yenilebilir peyzaj, Kentsel Tarım, Kampüs, Selçuk Üniversitesi, Kullanıcı deneyimi*

ID: 511

Alışveriş Merkezi Otoparklarında Gölge Ağaçlarının İncelenmesi ve Peyzaj Tasarım Önerisi: Konya M1 AVM Örneği

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Özet

Bu çalışma, Konya M1 AVM otoparkındaki gölge ağaçlarının detaylı bir incelemesini yaparak, sürdürülebilirlik prensipleri ve kullanıcı ihtiyaçları doğrultusunda geliştirilmesine yönelik kapsamlı bir peyzaj tasarım önerisi sunmayı hedeflemektedir. Günümüzde kentlerdeki geniş geçirimsiz yüzeylerin önemli bir bölümünü oluşturan otoparklar, kentsel ısı adası etkisini tetikleyerek, çevresel sorunlara ve kent estetiğinin olumsuz etkilenmesine neden olabilmektedirler. Bu nedenle, otopark alanlarına yapılacak bitkisel tasarım, özellikle uygun ağaç türlerinin seçimi ve doğru konumlandırılması ile doğrudan gölgeleme sağlayarak otopark yüzeylerinin ve çevredeki havanın sıcaklığını önemli ölçüde düşürebilir. Bu çalışma, Konya M1 AVM otoparkında bulunan mevcut ağaçların tür çeşitliliğini, büyüklüklerini, taç yapılarının gölgelendirmedeki etkinliğini ve genel sağlık durumlarını bilimsel yöntemlerle değerlendirecektir. Ayrıca, otopark kullanıcılarının gölge beklentileri, termal konfor algıları ve otoparkın genel estetiğine yönelik görüşleri dikkate alınarak otopark için ekolojik açıdan sürdürülebilir, estetik ve kullanıcı konforunu ön planda tutan yenilikçi bir peyzaj tasarım projesi geliştirilecektir. Önerilen proje, maksimum düzeyde gölge sağlayacak, park halindeki araçların aşırı ısınmasını engelleyecek ve dolayısıyla araç içi sıcaklığı düşürerek klima kullanımını azaltmaya yardımcı olacaktır. Bu doğrultuda proje kapsamında kullanılacak ağaç türleri, ideal dikim mesafeleri ve yerleşim planları detaylı olarak sunulacaktır. Aynı zamanda, seçilecek ağaçların mevcut ortama görsel bir zenginlik katması ve otopark kullanıcılarının memnuniyet düzeyini artırması hedeflenmektedir. Bu çalışmanın sonuçlarının, benzer özelliklere sahip alışveriş merkezi otoparklarının termal konforunu iyileştirme ve kullanıcı deneyimini zenginleştirme konularında uygulanabilir ve ilham verici bir model sunması öngörülmektedir.

Anahtar Kelimeler: *Otopark Tasarımı, Bitkilendirme, Kentsel Isı Adası, Mikroklima, Gölgeleme*

ID: 512

Physicochemical and nutritional values of tiger nut (*Cyperus esculentus*) oil from three regions of Côte d'Ivoire

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Abstract

In many rural areas of West Africa, the consumption of lipids by farmers is one of the problems affecting their nutrition and even their health. In Côte d'Ivoire, tiger nut, consumed as part of the traditional diet of rural populations in the north and centre of the country, is a potential source of dietary lipids. The aim of this study was to contribute to the valorisation of tiger nuts (*Cyperus esculentus*) through the physico-chemical characterisation of the oil extracted from tubers from three regions of Côte d'Ivoire. To do this, samples of tiger nut tubers were collected and the oil was extracted using standard methods. Tiger nut oils exhibited satisfactory physicochemical characteristics, with acid value ranging from 0.13 to 3.14 mg KOH/g oil, iodine value from 68.92 to 94.54 g I_2/100 g oil and saponification value from 174.2 to 185.13 mg KOH/g oil. The oils were rich in polyunsaturated fatty acids, with oleic acid being the most abundant (73 - 80%) and demonstrated greater oxidative indexes. Tiger nut oil from the three regions contained significantly higher levels of α-tocopherols and polyphenols. Due to these characteristics and nutritional properties, tiger nut oil presents significant potential for application in food, nutraceutical and cosmetic industries.

Keywords**:** *Tiger nut tubers; oil extract, physicochemical properties, fatty acids; antioxidants.*

Introduction

In Côte d'Ivoire, as in many other countries in West Africa, the nutritional needs of the population, estimated at 1 800 000 tonnes/year to ensure a quality diet, are far from being met (FAO, 2023). The population of Côte d'Ivoire, like that of most underdeveloped countries, consumes too few calories from fat. There is a significant difference between rural and urban populations; the former consumes less fat than the latter and their lipid diet is not necessarily balanced (Sahoré et al, 2017). Several oilseed crops are grown in the countryside, the best-known being cotton seeds, shea butter and oil palm. It seemed attractive to target additional oilseeds with very low value added and significant scientific and technological interest (Kanaté et al., 2025). Increasing the amount of lipids produced from these oilseeds will almost certainly lead to an improvement in the diet and hence the health of the population (Ouilly et al., 2017). Several species, including tiger nut (*Cyperus esculentus* L.), have been identified as a result of a number of studies carried out in different parts of the country (Yao et al., 2020; Nikiema et al., 2024).

Tiger nut is a sedge that also grows as a perennial or annual herb which is currently distributed mainly in Spain, Australia, North and South America, China and Africa (Yapi et al., 20121; Zhang et al., 2023). It is a high-yielding, high-value and commercially useful crop with multiple uses (Okoye & Ene, 2018). Tiger nut is rich in starch, with a content of 25-40 %, in carbohydrates (15-20 %) and protein (5-10 %) (Kouame et al., 2022; Wu et al., 2024). In addition, tiger nut is rich in dietary fibre (8-10 %), vitamins C and E (8-14 mg/100g), minerals (potassium, phosphorus, sodium, calcium, magnesium), polyphenols and other bioactive substances (Djikeng et al., 2022; Imo et al., 2024). Tuber has recently gained popularity as a functional food due to its biological properties, which include antioxidants, antibacterial, anti-inflammatory, anticancer, anti-sickling, aphrodisiac, anti-atherosclerotic and hepatoprotective effects (Olabiyi et al., 2017; Rebezov et al., 2021).

Tiger nut is widely used in Côte d'Ivoire, where it is known as tchongon in Malinké, Bété, Dida, and Bambara, atadjo in Apolo, shop in Koulango, and maguélé in Sénoufo (Alloko et al., 2022a). It is mostly produced in the country's northern and central regions, with three forms including black, brown, and yellow. Tiger nut tubers can be consumed raw, roasted, or ground into beverages and flour. Edible oil potentials of tiger nut tuber grown in Côte d'Ivoire was investigated (Alloko et al., 2022a; Yao et al., 2020). Despite its high value in industrial applications, tiger nut oil is undervalued in Côte d'Ivoire. In fact, the oil from the tubers is still not part of the local diet. Therefore, this study investigates the physiochemical properties and nutritional benefits of tiger nut oil. The data will inform on the nutritional value of the seed and assist in assessing seed oils for additional applications, including biodiesel and oleochemical sources, thereby enhancing the value of these oils in the country.

Materials and Methods

Materials

The tiger nut tubers used in the research were provided from three regions in the North and the centre north of Côte d'Ivoire. The regions were Dabakala (Hambol region, 7° 41'north, 5° 01'west), Ferké (Tchologo region, 9° 35'north, 5° 11'west) and Korhogo (Poro region, 9° 25'north, 5° 38'west). Yellow tiger nut tubers were collected from January to March 2024 from a pool of women traders in each zone at a rate of 5 kg per woman. A total of 50 kg of tiger nut tubers were collected from each zone and taken to the laboratory for further examination. The tubers were sorted to eliminate those with defects and 5 kg was deducted after homogeneous mixing of the samples collected from each zone. This final quantity was sun dried for one week. The dried seeds were then ground using a hammer mill (Forplex). The ground seeds were sealed and stored in a desiccator until analysis.

Oil extraction

Tiger nut oil was obtained after maceration of the ground tiger nuts mixed with n-hexane at a ratio of 1:10 (g/v) for 6 hours at room temperature. The hexane was removed after extraction using a rotary evaporator (BÜCHI). The oil obtained from each sample was stored in a dark bottle in a refrigerator at 4°C until it was used for various analyses. The yield of lipid extraction was calculated according to formula (1): Yield (%) = (m0/m1) × 100 (1) m0 is the mass of the extracted fat (g), m1 is the mass of the ground tiger nuts.

Analysis of oil quality

Quality indexes

The standard methods of the International Organisation for Standardisation (ISO) were used to analyse oil quality. Acid value and free fatty acid content (ISO 660); iodine value (ISO 3961); peroxide value (ISO 3960); saponification and ester values (ISO 3657); unsaponifiable matter (ISO 3596); refractive index (ISO 6320); relative density (ISO 6883); insoluble impurities (ISO 663); anisidine value (ISO 6885); unsaponifiable matter (ISO 3596). The Totox value was calculated according to the following equation as mentioned by Djikeng et al. (2024): Totox = 2 PV + AV. Titrimetric methods were used to determine the acid, peroxide, iodine and saponification values of all samples.

Polyphenols content

Polyphenols content was evaluated by the Folin-Ciocalteu colorimetric method according to Michui et al. (2022) with slight modifications. The samples were prepared according to the following procedure: 2 g of the tiger nut was dissolved in 5 mL of hexane in an Erlenmeyer flask. Liquid-liquid extraction of antioxidants from the oil sample was then performed three times with 5 mL of methanol. Then the methanolic phase is recovered using a separating funnel. A total of three identical extractions are performed and the methanolic phases are collected and concentrated in the rotary evaporator. 50 µL of the methanol fraction was treated with 1 mL of Folin-Ciocalteu reagent diluted tenfold in distilled water. This mixture was incubated for 10 min. To this sample, 1 mL of sodium carbonate solution (7%, m/v) was added. Absorbance was measured at $\lambda = 760$ nm relative to distilled water. The total polyphenols were expressed in mg GAE/100g oil. A blank solution was also prepared in the same way, using an equivalent amount of methanol instead of the extract.

Vitamin A and Tocopherol Content

Analysis of retinol and α-tocopherol was performed by high pressure liquid chromatography (Acquity UPLC chromatograph, Waters Corporation, Milford, MA, USA) according to ISO 14565. Vitamin and tocopherols were identified based on retention times determined separately for retinol and α-tocopherol, and their contents were estimated using external calibration curves.

Analysis of Fatty Acids

To evaluate the fatty acid content of tiger nut oil, fatty acid methyl esters were prepared according to the SRPS EN ISO 12966-2 method. Fatty acid composition was analysed by gas chromatography (3900, Varian CPG, Sydney, Australia) equipped with a flame ionisation detector and a capillary column CP - select CB for FAME fused silica WCOT (50 m × 0.25 mm, d = 0.25 µm). Helium was used as the carrier gas. The initial column temperature of 140 ◦C was held constant for 3 min, then increased to 220 ◦C (at a rate of 3 ◦C/min) and held for 5 min. Finally, the column temperature was raised to 240 ◦C (at a rate of 2 ◦C/min) and held for 10 min. The injector and detector temperatures were set at 250 ◦C. The individual peaks were identified by comparison of their retention times with the standard mixture of 18 FAME methyl esters. The results were expressed as percentage by weight of the total fatty acid content.

Statistical Analysis

The results of the chemical analyses performed in triplicate were analysed statistically using IBM SPSS Statistics 20 (IBM, Chicago, IL, USA). Tukey's multiple comparison procedure was used to compare the obtained results to each other. Identical letters in rows denote the lack of differences at a significance level $\alpha = 0.05$.

Results and Discussion

Results

Physico-chemical parameters

The physico-chemical parameters of tiger nut oil from the different regions are shown in Table 1. The analysis indicated that there was not a significant difference (P>0.05) in all the parameters analysed except for insoluble impurities. The same observation was noted on the oil yield percentage obtained for these three regions (P>0.05). Regarding the insoluble impurities, values obtained from the tiger nut oil samples ranged from 0.005 to 0.02%. Regarding the acid value of the tiger nut oil samples, the results show a significant difference (p<0.05) with the three regions and all the tiger nut oil samples have lower values (from 0.13 to 3.14 mg KOH/g oil) than the recommended value of 4 mg KOH/g oil. The same observation was made for free fatty acid with values varying significantly (p<0.05) from 0.07% to 1.57%. The Korhogo department recorded the highest percentage. Similarly, the results showed that the iodine value of tiger nut oil from the different regions ranged from 68.92 ± 0.79 to 94.54 ± 6.50 g I_2/100 g oil. The highest value was recorded in Korhogo Department and the lowest in Dabakala Department. The analysis of chemical properties revealed that there was no significant difference (P> 0.05) in the parameters of saponification value, ester value and unsaponifiable matter content with values ranging from 174.2 ± 2.70 to 185.13 ± 6.43 mg KOH/g oil, 171.05 ± 2.88 to 183.02 ± 6.15 mg KOH/g oil and 1.48 ± 0.03 to 1.62 ± 0.01 %

Table 1. Physico-chemical properties of tiger nut oil from the three regions

Parameters	Dabakala	Ferké	Korhogo
Yield (%)	14.17 ± 0.93[a]	14.73±0.74[a]	14.68±0.64[a]
Relative density at 20°C	0.91 ± 0.0[a]	0.91±0.0[a]	0.91±0.0[a]
Refractive index	1.4567 ± 0.01[a]	1.460±0.01[b]	1.459±0.01a[b]
Moisture and volatile contents (%)	8.52± 0.01[a]	8.57± 0.01[a]	8.49± 0.01[a]
Insoluble impurities (%)	0.005±0.003[a]	0.01±0.001[a]	0.02±0.001[b]
Acid value (mg KOH/g)	0.13 ± 0.0[a]	2.11 ± 0.27[b]	3.14 ± 0.22c
Free fatty acid (%)	0.07 ± 0.0[a]	1.1 ± 0.14[b]	1.57 ± 0.11c
Iodine value (g I_2/100 g)	68.92 ± 0.79[a]	76.92 ± 3.83[a]	94.54 ± 6.50[b]
Saponification value (mg KOH/g)	174.38 ± 5.84[a]	175.13 ± 6.43[a]	174.20 ± 2.70[a]
Ester value (mg KOH/g)	174.25 ± 5.84[a]	173.02 ± 6.15[a]	171.05 ± 2.88[a]
Unsaponifiable content (%)	1.53 ± 0.01[a]	1.48 ± 0.03[a]	1.62 ± 0.01[a]

n=3 values are presented as mean±SD. Values followed by the same letters in the same row are are not significantly different at p ≤ 0.05.

Table 2. Oxidative indexes of tiger nut oil from the three regions

Parameters	Dabakala	Ferké	Korhogo
Peroxide value (meq O_2/kg)	3.17 ± 0.29[a]	3.83 ± 1.15[a]	4.05 ± 0.30[a]
Anisidin value	2.59 ± 0.12[a]	3.40 ± 0.46[b]	3.58 ± 0.90[b]
Totox value	8.92 ± 0.70[a]	11.06 ± 2.76[a]	11.68 ± 0.69[a]

n=3 values are presented as mean±SD. Values followed by the same letters in the same row are are not significantly different at p ≤ 0.05.

Oxidative indexes

The oxidative indexes analysis of tiger nut oil extracted from the three regions are presented in Table 2. With values ranging from values 3.17 ± 0.29 to 4.05 ± 0.30 meq O_2/kg oil, the peroxide index revealed no significant difference (P> 0.05) from the three regions. For the anisidin value, significant differences were found between the tiger nut oil values according to the regions (p<0.05). The tiger nut samples from the regions of Ferké and Korhogo had the highest para-anisidine values. As for the Totox value, all types of tiger nut oil samples showed no significant difference (P> 0.05) regardless of the three regions.

Polyphenols and vitamins content

The polyphenols and vitamins parameters of tiger nut oil from the different regions are shown in Table 3. The analysis showed that there was a significant difference (P<0.05) in all the parameters analysed. Indeed, the content of polyphenols in the evaluated tiger nut oil ranged from 14.81 to 22.54 mgGAE/100 g. Tiger nut oil from Korhogo department contained approximately 1.2 to1.5 times more polyphenols than tiger nut oils from the other regions. In addition, tiger nut oil from the Korhogo department had the highest vitamins content, with a value of α-tocopherol of 54.12 mg/kg and 7.93 ± 0.37 mg/kg for retinol.

Fatty acids composition of tiger nut oil from the different regions

The fatty acid composition is given in Table 4. The GC analysis results show a significant difference (P<0.05) between the free fatty acid compositions of tiger nut oil from the three regions. The most abundant fatty acids in

the tiger nut oil samples were oleic acid (C18:1), linoleic acid (C18:2), palmitoleic acid (C16:1) and stearic acid (C20:0). The main fatty acid found in both materials was oleic acid, 72.69 ± 1.1% to 79.68 ± 0.98% in tiger nut oil from the three regions, with Korhogo showing a higher value. Linoleic acid (C18:2) was the second most abundant fatty acid determined in the tiger nut oil sample. The high content of SFA in the tiger nut oil samples from the three regions was attributed to the presence of oleic, linoleic and palmitoleic acids. The PUFA content was slightly higher in tiger nut oil from Korhogo (88.73%) than in tiger nut oil from Ferké and Dabakala (83.42 and 84.51%).

Table 3. Polyphenols and vitamins (tocopherols, retinol) content of tiger nut oil from the three regions

Parameters	Dabakala	Ferké	Korhogo
Polyphenol (mg/100g GAE)	14.81 ± 0.14^{a}	19.50 ± 0.19^{b}	22.54 ± 0.59^{c}
α-tocopherol (mg/kg)	144.11 ± 0.37^{b}	136.07 ± 0.41^{a}	154.12 ± 1.03^{c}
Retinol (mg/kg)	7.37 ± 0.31^{ab}	6.70 ± 0.40^{a}	7.93 ± 0.37^{b}

n=3 values are presented as mean±SD. Values followed by the same letters in the same row are are not significantly different at $p \leq 0.05$.

Table 4. Composition of fatty acids of tiger nut oil from the three regions

Parameters	Dabakala	Ferké	Korhogo
Lauric acid (C12:0)	0.44 ± 0.16^{b}	0.10 ± 0.0^{a}	0.13 ± 0.04^{a}
Myristic acid (C14 :0)	1.29 ± 0.03^{c}	1.13 ± 0.02^{b}	0.88 ± 0.06^{a}
Palmitic acid (C16 :0)	0.34 ± 0.0^{a}	0.24 ± 0.01^{a}	0.33 ± 0.10^{a}
Palmitoleic acid (C16 :1)	9.47 ± 0.80^{b}	9.25 ± 0.43^{b}	5.63 ± 0.51^{a}
Stearic acid (C18 :0)	4.83 ± 0.33^{b}	4.18 ± 0.21^{a}	3.72 ± 0.20^{a}
Oleic acid (C18: 1)	73.31 ± 0.76^{a}	72.69 ± 1.1^{a}	79.68 ± 0.98^{b}
Linoleic acid (C18: 2)	9.64 ± 0.47^{b}	11.42 ± 0.23^{c}	8.48 ± 0.30^{a}
Linolenic acid (C18 :3)	0.13 ± 0.02^{a}	0.16 ± 0.02^{a}	0.25 ± 0.03^{b}
Arachidic Acid (C20 :0)	0.29 ± 0.02^{b}	0.43 ± 0.04^{b}	0.72 ± 0.06^{c}
SFA	16.32	15.09	11.08
MUFA	73.65	72.93	80
PUFA	83.42	84.51	88.73

n=3 values are presented as mean±SD. Values followed by the same letters in the same row are are not significantly different at $p \leq 0.05$.

Discussion

The results of oil extraction from tiger nut tubers showed no significant difference between the different regions. Oil contents ranged from 14.17 ± 0.93% to 14.73 ± 0.74%. The oil yield values obtained in this study were lower compared to the one reported by Zhen-Shan Zhang et al (2023) and Keskin et al (2024). However, our values are similar to those of Djikeng et al (2022). These differences can be attributed to the extraction methods and the maturity stage of the tubers (Hsu *et al.,* 2006). The results of the physical characterisation of the tiger nut oil samples show no significant difference in origin, except for impurities. The physical parameters studied were relative density, refractive index, moisture content and impurities. The relative density obtained for the three oil samples is 0.91. This value is comparable to that obtained by Yao et al. (2018) and Aljuhaimi et al. (2018). As for the refractive index values, values obtained were between 1.459 and 1.460 and are comparable to those reported by Adel et al. (2015).

The evaluated tiger nut oils exhibited acid value (AV) ranging from 0.13 to 3.14 mg KOH/g of oil which remained well below the Codex Alimentarius's standard limit of 4 mg KOH/g. These low acid values obtained for tiger nut oil are an indication that the triglycerides present in the tiger nut sample have not been hydrolysed, an indication that the oil is less susceptible to lipase action. Keskin et al (2024) reported that AV values for yellow tuber tiger nut oil obtained through cold-press machine extraction of 3.63 ± 0.02 mg KOH/g of oil. The free fatty acidity (FFA) of the oil ranging from 0.07 to 1.57% linoleic acid. Similar trends were observed for tiger nut oils extracted by different method (Duman, 2019; Miao *et al*., 2022). The iodine value provides information on the degree of unsaturation of the fatty acids present in the oil. In the current study, iodine values ranged from 68.92 to 94.54 g I_2/100 g of oil. The results are comparable to those reported by Sabah et al. (2019), with an iodine value ranging from 70 to 80 g I_2/100 g of oil. The tiger nut oil samples from the three regions analysed showed an average saponification index of between 174.20 and 175.13 mg KOH/g oil, which is higher than the values reported by Dumas (2019) from chufa seeds varieties in Turkey. The ester indices were of the same order and all slightly lower than their saponification index. The unsaponifiable fraction content varied from 1.48% to 1.62% among the various tiger nut oil samples studied. The unsaponifiable fraction content of the oils examined is higher than that of certain conventional oils such as cotton seed oil (0.52%) and peanut oil (0.33%) (Zoué et al., 2012). The presence of unsaponifiable compounds could add value to these oils, making them suitable for use in the food sectors. The

determination of the PV of oils and fats informed on their primary oxidation state which must be less than 15 meq O_2/kg of oil, the limit recommended by the FAO for vegetable oils intended for human consumption (Codex, 2023). In this study, the peroxide values, between 3.17 and 4.05 meq O_2/kg of oil, were well in line with this recommendation. For an accurate evaluation of the oil's oxidation state, it is crucial to integrate the measurements of the para-anisidine and peroxide values. Para-anisidine value measures the level of secondary oxidation products, such as aldehydes, ketones, hydrocarbons, alcohols, esters, and acids, formed from the breakdown of primary oxidation products (Djikeng et al., 2024). The relatively low *p*-anisidine value of the tiger nut oils suggests that primary oxidation products have not significantly degraded, indicating that the oils were safe for consumption concerning oxidation and hydrolysis products. A Totox value of 10 is the threshold for determining acceptable quality in edible oils (Bojanowska and Lamarska, 2016). The calculated Totox value, as a measure of the total oxidation profile of the tiger nut oils from the three regions, ranged from 8.92 to 11.68 indicates high primary and secondary oxidative stability. Polyphenols are natural antioxidants with the ability to inhibit the oxidation process in oils (Rakita et al., 2024). Results showed an average total polyphenol content ranging from 14.81 to 22.54 mg GAE/100 g which was much lower than total phenol content in tiger nut oil reported by Alloko et al (2022b). However, these results are quite similar to those reported by Zhang et al (2023). The significant quantity of tocopherols found in all tiger nut oil from the three regions could contribute to its high oxidative stability. Similar to this study, previous studies have reported higher concentrations of α-tocopherols in tiger nut oils (Zhang et al., 2023). The low levels of vitamin A (retinol) observed in the tiger nut oils samples could be explained by the absence or very low presence of vitamin A in the form of retinol in tubers plants from which these oils are extracted (Yao et al., 2018). The results obtained could also be influenced by the degradation process of the samples during the assay procedure. The most dominant MUFAs in tiger nut oils from the three regions were oleic acid. Other researchers have shown similar levels of these fatty acids. Higher percentages of oleic acid (66-78%) were reported by several authors (Hu et al., 2018; Guo et al., 2021). Due to its unique fatty acid profile, tiger nut oil could be suitable for direct consumption, including use in the enrichment of various food products. Its potential nutraceutical benefits suggest its use in the development of functional foods and nutraceuticals aimed at promoting health (Zhang et al., 2023).

Conclusion

This paper evaluated the physico-chemical parameters of tiger nut oil from three regions of Côte d'Ivoire. The analysis of physico-chemical parameters showed that the oils obtained from the three regions had similar yields and were of satisfactory quality. Tiger nut oils were rich in polyunsaturated fatty acids (83 - 88%), of which oleic acid was the most abundant (73 - 80%). High content of unsaturated fatty acids raises the possibility of including tiger nut oils in the human diet. Tiger nuts oils from the three regions exhibited a higher content of α-tocopherols and polyphenols and demonstrated greater oxidative indexes. In view of all these potentialities and qualities, tiger nut oils from the three regions presents significant opportunities for application across diverse industries, including food, nutraceuticals, animal feed, and cosmetics. Future investigations may focus on investigating the toxicological and antimicrobial effects of tiger nut oils before using them as supplements in food, nutraceutical and cosmetic industries.

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Conflict of interest
The authors declare no conflict of interest

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Developments of Food Industry 4.0 in Europe

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Abstract

Food security risks are increasing due to the global population explosion and climate change. Therefore, it is necessary to develop plans to conserve resources and ensure their sustainability using modern technologies to achieve this purpose. This report aims to examine the advancements in the European Food Industry 4.0. The Fourth Industrial Revolution (Industry 4.0) is gaining traction as a critical driver of sustainable growth and a valuable catalyst for resolving global issues. Technology from the Fourth Industrial Revolution is now widely used in the food business, and its use has increased dramatically in recent years. These innovations will lower manufacturing costs, improve food safety and quality, use less energy and resources, and decrease food loss and waste. The use of technology 4.0 has accelerated over the past few years due to its high efficiency in the food industry. Therefore, this review aims to shed light on technology 4.0 in Europe and its development over the past. The food processing business is one of the numerous industrial sectors that industry 4.0 technologies have redefined and transformed in the last few years. Several Industry 4.0 technologies have become more well-known and thriving in the food, safety, and quality sectors.

Key Words: *Food Industry 4.0, Agriculture, Europe*

Introduction

In the last several years, our world has faced unheard-of difficulties, chief among them being climate change's severe and pervasive effects. In the meantime, as the world's population rises and is predicted to reach 9.7 billion by 2050, there will be a 56% increase in the need for food (van Dijk et al., 2021). Globally, the effects of climate change on government policies are complex and affect many facets of society, including the environment, politics, economy, and ecology. The consequences of different climates in different countries vary, as do the socioeconomics, infrastructure, institutional capacity, and resilience of health systems. Consequently, there are regional differences in the complexity and capability associated with the impacts of climate change on health (Abbass et al., 2022). The pace of population expansion and climate change will significantly disrupt the global food supply, leading to a host of nutritional issues shortly. As the world's population approaches 8 billion people, it will become more difficult for humanity to meet the expanding population's food demands. Climate change may impact food production, a severe worry (Bağdatlı et al., 2023). For instance, forests, crucial food sources in many places, may be destroyed by increasing sea levels brought on by climate change (Elsheikh et al., 2023). Climate change directly affects food security and the source of income for those working in the food industry, including value chains. Currently, the global population affected by famine reached its peak in 2014. Climate conditions hav an imbat on the Food Distributions rotu, makin it difficult for people to visit markets in a variety of ways physically. Heavy rain, snow, storms, bridges, road vandalism, and overflowing transit channels all imbat the infrastructure (Raj et al., 2022).

Food shortages are a growing concern, driven by rising temperatures. The likelihood of several 'breadbasket failures' leading to a shock in food prices is rising. For instance, the likelihood of maize production misplacement is more than 10% among the top four divisions that produce the most maize (87% of total output); this percentage increased from 7% each year under a two °C temperature rise to 86% under a four °C increase (Ogunkalu, 2024). However, there is hope in the potential of technological advancements. The food processing industry is expected to evolve to produce foods with higher nutritional value, less resource consumption, biodiversity preservation, and minimal environmental impact in resilient systems to meet this growing demand with complementary initiatives to end hunger and food insecurity (Sachs et al., 2019). Significant adjustments are required, particularly in the food processing business, even if this requirement is hoped to be satisfied. It is anticipated that the fundamental principles of our society will change and become more robust, adaptable, flexible, and sustainable. Technological advances are vital components that will enable progress in food processing toward solving current and future issues. Elevated connectivity and automation via computer power are critical elements that might revolutionize food production systems (Augusto, 2020). Over the last twenty years, advancements in artificial intelligence (AI), consumer technology, computer power, and connection have all contributed to increased accessibility and a surge in biotechnology, robotics, e-commerce, and nanotechnology research and development. Food production is

undergoing significant changes due to 'Big Data.' Beyond these developments, blending technologies not usually combined is starting to encroach on the digital, physical, and chemical-biological domains, encouraging the fusion of new scientific fields with the so-called conventional food sciences (Chapman et al., 2022).

The aforementioned alterations, in tandem with technology integration across the food production, storage, and packaging process and throughout the value chain, define the fourth industrial revolution. Among other things, his fourth revolution is determined by the absence of borders and rapid business changes (Lee et al., 2018). In essence, the goal of the Fourth Industrial Revolution, also known as Industry 4.0, is to establish intelligent processing systems by increasing high-level automation and connectivity (between sensors, devices, machines, and people, for example) (Morella et al., 2021). One of the fundamental elements of Industry 4.0 is its interdisciplinary character, which incorporates a wide variety of information from the digital, biological, and physical domains (Chapman et al., 2021). This combination of qualities is needed to improve food quality, decrease food loss, and encourage the development of more efficient production techniques. It is crucial to note that there is no global consensus on the elements of Industry 4.0 (Ghobakhloo, 2018). This study analyzes Europe's Food Industry 4.0 developments, highlighting the industry's prospects and challenges.

Developments of Food Industry 4.0 in Europe

The Industrial Revolutions were defined by the advent of revolutionary developments in industrial production, which were primarily connected to technological advancements. The first industrial revolution (18th–early 19th century) defined the initial shifts towards intensifying working activities by creating and upgrading steam engine-driven equipment. During this period, the textile, coal, iron, and chemical industries flourished, and the production of certain food items shifted from home to factory settings (Koetsier, 2019).

The first industrial revolution's increasing mechanization and the extension and intensity of working activities led to the second industrial revolution in the 19th–early 20th century.

In addition, electricity became more common and replaced steam-powered equipment in industrial settings, which made large-scale production possible (Zhang & Yang, 2020). In the second decade of the 20th and early 21st centuries, the transition from analog to digital electronic systems signaled the start of the third industrial revolution, often known as the digital revolution. Significant technology developments like computers and the Internet have made it possible to communicate more quickly and interact with people worldwide. Electronic systems were also used for automation in manufacturing. To fulfill the growing demand from industrial, public, and domestic users throughout this time, nuclear energy research and application became more crucial (Xu et al., 2018).

Industry 4.0, or the contemporary 4IR (early 21st century), is defined by fully automated processes, integration with digital technology, and an emphasis on the Internet above all other factors. This ongoing change, which combines digital, biological, and physical components, enables real-time networking and communication among all industry stakeholders (Maynard, 2015). Mass production automation incorporates customization and personalized products. The growth of Industry 4.0 is linked to several essential variables, including digital twins, CPS, big data, blockchain, artificial intelligence (AI), intelligent sensors, cybersecurity, the Internet of Things (IoT), robotics, and cybersecurity. The food industry's production and operational efficiency have increased thanks to these cutting-edge digital and other emerging technologies. However, they have also negatively affected environmental sustainability and particular disturbances to the food supply chain (Olah et al., 2020). Robots are predominantly used in the food processing sector for pick-and-place operations such as packaging, sorting, and packing (Wang et al., 2022).

Robotic automation functions optimally when it addresses or improves specific manufacturing and processing scenarios (Dzedzickis et al., 2022). Robotics allows for rapid and straightforward reconfiguration into new work environments and procedures. Repetitive motion also reduces worker injuries, improving the working environment. Reduced production times and costs, as well as reduced waste material, were guaranteed by increased productivity. These benefits ensure that the company will always have an advantage over competitors. Robotics and Sector 4.0 technologies have long been used in food processing applications. However, their adoption rates are still low because of specific issues that need to be resolved before they can be widely used in the food sector.

For example, the food industry's stringent hygienic standards to guarantee food safety are among these problems, as are financial obstacles resulting from the exorbitant prices of buying and operating robotics at the moment (Wang et al., 2022). Artificial biomimetic technologies (E-noses, E-tongue, and computer vision) are clever techniques used in food processing based on appearance, taste, and smell variations. Chemical sensors, equipped with an AI system with access to a database of potentially harmful odors, can accurately discern between different food odors.

E-noses might be helpful in a food processing setting to help detect pollutants. For example, an E-nose with chemo-metric methods might be a trustworthy tool for tracking food drying procedures (Sun et al., 2019). Additionally, computer vision can disclose food's nutritional content (Kakani et al., 2020). Imaging and sensing sensors can also detect food residue on equipment. AI can also grade food cleanliness, monitor temperatures, and ensure employees wear the appropriate PPE. Monitoring tools can identify and follow individuals, their movements, and their clothes.

Face and object recognition may detect Masks or hair coverings (Kumar et al., 2021). Food safety is a critical concern in the food industry. Better monitoring using networked sensors makes it easier to identify food processing safety concerns and take action before the contamination spreads. As a result, IoT can identify safety concerns earlier than conventional techniques and instantly communicate the relevant data to take immediate action. It guarantees little production disruption and minimizes safety hazards while avoiding the need to spend resources for a batch that would otherwise have to be thrown out and squandered (Hassoun et al., 2023). IoT and biosensors can detect food contamination and send notifications that immediately cut off supply lines (Zhang et al., 2022). Food quality evaluations, food safety, and food production use IoT technologies in various ways.

The technologies that constitute Industry 4.0 as a whole and food processing technologies grew simultaneously as advancements in food science. Combining these two improves food safety and quality while catering to customer tastes and developments in the food processing sector (Hassoun et al., 2023). By leveraging our technical expertise on the global food system, we can develop standards, guidelines, and testing protocols that will enable the food business to adopt sustainable and, most importantly, safer practices. Furthermore, one area where technology may profit from a deeper comprehension of the content of food is native production (Serazetdinova et al., 2019). Therefore, technology 4.0 has accelerated over the past few years due to the food industry's high efficiency.

Conclusion

The Fourth Industrial Revolution is becoming increasingly popular as a catalyst for sustainable growth and a way to address previously recognized global problems. The food industry has recently significantly increased its use of Fourth Industrial Revolution-era technologies. These developments will lower production costs, improve food quality and safety, conserve energy and resources, and reduce food loss and waste. One of the numerous industrial areas in which business 4.0 technologies are redefining and transforming is the food processing industry, which has recently attracted much attention.

Advances in food science have led to a corresponding rise in food processing technology and the technologies that make up Industry 4.0 as a whole. Several Industry 4.0 technologies have been more widely accepted and thriving in the food, safety, and quality sectors in recent years. We can develop standards, guidelines, and testing procedures that will enable the food sector to adopt sustainable and, most crucially, safer practices by pooling our technical knowledge of the global food system.

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Effect of Adding Camel Hump Fat on Quality Attributes of Beef Burger

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Abstract

The study was conducted to determine the sensory properties of beef burgers manufactured with different levels of camel hump fat. The hump fat, which has low cholesterol, is successfully used in many regional countries.is almost neglected as a binder in processed meat production in Sudan. The samples were weighed and burger patties were formulated in 5 treatments T1: 0% T2: 10%, T3: 15%, T4: 20% and T5: 25% hump fat, respectively. The treatments were subjected to 4 replications. The sensory evaluations included tenderness, juiciness, colour, flavour and overall acceptability. The data were statistically analyzed using variance analysis for a completely randomised design using the SPSS version 8.0 computer program. LSD did mean separation, and the values were expressed as means and standard error. The difference between mean values was significant at $P < 0.05$. The flavour (T1: 5.54 ,T5: 5.11).juiciness (T1: 5.64 T5: 5.45) and total acceptability (T1: 6.11, T5: 5.57) decreased by increase of camel hump fat. The study concluded that camel hump fat can be added to the beef burger formulation. However, the negative effect of flavour can be solved by increasing the level of spices.

Introduction

Sudan has a huge livestock population, estimated to be more than one hundred and seven million heads. Camels are important livestock species uniquely adapted to hot and arid environments. One-third of the total camel population is found in Somalia, and 60% is found within the borders of Somalia, Sudan, Kenya, and Ethiopia. Australians have lately started to look at camel as a source of meat (Fathi, 2005). Meat and meat products are essential components in human diets; their consumption is affected by various factors. The most important are product consumer and environment-related characteristics (Colmenero et al., 2001). A burger is a minced meat product. The minced meat is mixed with condiments and spices, shaped, and cooked by frying or baking (Gurjral et al., 2002). The types of seasoning used vary depending on the taste requirement, from mild to hot and spicy. Humans' use of animal fats may well predate civilisation. As the depot fats in animals are readily visible during the butchering of a slaughtered animal, are easily harvested, and are available without the need for plant domestication or the adoption of established agriculture, animal fats were probably the first lipids consumed by humans. Lipids support multiple biological functions in the body. They serve as the structural building materials of all cell and organelle membranes. Lipids are the most efficient fuel for living organisms, containing more than twice the energy content of carbohydrates and proteins on a weight basis (Sbihi et al., 2013).

Fat in meat products plays an important role in stabilising meat emulsions, reducing cooking loss, improving water holding capacity, providing juiciness and tenderness and has considerable effects on the binding, rheological and structural properties of the meat products (Yoo et al.2007). Fat is important in meat products since it affects technological properties and sensory aspects, mainly hardness and juiciness (Ozvural et al., 2008). The level and type of fat in emulsion-type sausages affect the percentage of cooking losses. In this regard, Serdaroglu et al. (2004) found a possible relationship between increasing cooking yield and higher fat retention in beef patties. In addition to the serious health concerns associated with animal fat, lipid and protein oxidation poses a significant threat to meat quality. Oxidative reactions occurring in muscle foods during handling, processing, and storage can lead to undesirable sensory changes and a decline in nutritional value. Therefore, reducing fat content is widely recognized as a key strategy for improving the nutritional profile of foods and producing healthier products. This is particularly important in the meat industry, where certain meat products contain high levels of fat (Huda et al., 2014). From a chemical perspective, camel meat contains more moisture than beef. Studies have shown that camels have a slightly higher moisture-to-protein ratio compared to beef or lamb (Babiker & Tibin, 1989). Babiker and Tibin (1989) found that, compared to beef, camel meat has significantly higher protein content and lower intramuscular fat. Additionally, camel meat contains notably lower levels of sarcoplasmic protein than beef. Given these characteristics, camel meat presents a viable alternative for addressing animal protein shortages.

Camel meat is the least studied and is wrongly believed to be of lower nutritive value and quality than other red meat, despite their ability to produce good quality meat at comparatively low cost under highly harsh environments (Skidmore, 2005). Camel is suitable for exploiting arid areas, which constitute an important resource for some countries such as Sudan, Somalia, and Mauritania. Its meat represents about 8% of the meat production in the Arab countries (Kadim et al., 2008). Therefore in The objectives of this study were To determine the sensory properties of burgers manufactured with different levels of camel hump fat.

Materıals And Methods

Materials: Seven and half Kilo grams of beef meat and 100 gm of beef fat were purchased from the University of Khartoum project for animal production. One kilogram of sample camel hump fat was purchased from Tambull Meat Market (East Gazira State) and stored in ice in a thermal container before travelling to Shambat (Khartoum North), University of Khartoum and stored in a deep freezer at -18c till use. Mixes of spices were purchased from Khartoum North Market, Khartoum State, Sudan and were cleaned and grind by an electric grinder separately (cardamom, cinnamon, coriander, and fennel).

The meat samples were thawed overnight in a refrigerator at 4°c. Each of the samples was thoroughly ground. Random samples were taken from each batch to determine the fat content. The person square method was adopted to formulate treatments with different fat percentages. The remaining samples were thoroughly wrapped and frozen at -18°C until later used.

Treatments formulation: Five treatments were formulated (T1: Control 0%, T2: 10%, T3: 15%, T4: 20% and T5: 25% hump fat) with four replications as listed in table (1). It contained Meat, Beef fat, hump fat, salt, ice water, powdered milk, bread, sugar, and spices (Cardamom, Cinnamon, Coriander and Fennel).

Table 1: Treatments formulation of burger meat

Treatments	Composition of burger (%)							
	Meat	Hump fat	Bread crumps	Salt	Sugar	Ice water	Spices	Milk powder
1	71.5%	0	13	1.5	1	8	2	3
2	61.5%	10	13	1.5	1	8	2	3
3	56.5%	15	13	1.5	1	8	2	3
4	51.5%	20	13	1.5	1	8	2	3
5	46.5%	25	13	1.5	1	8	2	3

All spices (cardamom, cinnamon, coriander and fennel) and salt were added equally to each treatment.

Burger formulations: Meat and fat for each treatment group were ground separately through an electrical meat grinder, the meat through an 8 mm plate and the fat through a 6 mm plate. Samples were taken from the meat for proximate analysis, as AOAC (1990) described. Then, the rest of the ingredients were thoroughly mixed by hand, and the mixture was reground through a 5 mm plate. Finally, burgers were formed weighing 100 gm with 9 cm diameter and 5 – 10 mm thick. After formulation, the burger was packed into suitable plastic bags, labelled, and immediately transported to a freezer at -18°C until it was analysed.

Sensory evaluations: Sensory panel evaluation was conducted in sensory evaluation facilities of Meat Production Department, Faculty of Animal Production, University of Khartoum. Samples were thawed overnight in the refrigerator at 4°C and cooked by peanut oil frying for 2-5 minutes on each side. The samples were turned every few minutes until cooked. Each patty was cut into small pieces and served warm to the panellist. Twelve semi-trained panellists evaluated the warm meat samples. Panellists evaluated each meat sample for tenderness, colour, flavour, juiciness and overall acceptability using an 8-point scale score (hedonic scale) card described by Cross et al. (1978). The highest score of 8 is extremely colourful, tender, flavorful, juicy and acceptable, and the lowest score of 1 is inferior in colour, tenderness, flavour, juiciness and overall acceptability (appendix). Tap water was available for use between testing samples.

Statistical analysis: The statistical analysis for recorded data was done using variance analysis for a completely randomized design (CRD) using a general linear model (statistical program, version 8.0). LSD did mean separation, and the values were expressed as means and standard error.

Results

Colour: The effect of the addition of different levels of hump fat to beef burger colours is illustrated in Table (2). The results showed that T4(20% hump fat) and T3 (15% hump fat) had the highest colour, followed by T2, T1 and T5, respectively, with no significant difference (P ≤0.05) between the treatments.
Tenderness: The effect of adding different levels of hump fat to beef burger tenderness is presented in Table (2). The results showed that T4 (20 % hump fat) showed the highest tenderness, followed by T1, T2, T3 and T5, with no significant difference (P ≤ 0.05) between these four treatments.
Flavour: The effect of the addition of different levels of hump fat to the beef burger is presented in Table (2). The results showed that T1 (0% hump fat) showed the highest flavour, followed by T2, T3, T4 and T5, respectively, with no significant difference (P ≤ 0.05) between the treatments.
Juiciness: The effect of adding different levels of hump fat to beef burgers on juiciness is illustrated in Table (2). The results showed that T4 (20 % hump fat) showed the highest juiciness content, followed by T3, T1, T5 and T2 lowest, respectively, with no significant difference (P ≤ 0.05) between the treatments.
Overall acceptability: The effect of the addition of different levels of hump fat on beef burger acceptability is presented in Table (2). The results showed that T1 (0% hump fat) showed the highest acceptability score with no significant difference (P > 0.05) with the other treatments, followed by T3, T4, T2 and T5 respectively.

Table (3): The effect of adding different levels of hump fat to beef burger panel test

Parameter / Treatments	Color	Tenderness	Flavor	Juiciness	Overall acceptability
T1 0%	5.68	6.04	5.54	5.64	6.11
T2 10%	5.79	5.71	5.32	5.29	5.68
T3 15%	5.82	6.25	5.21	5.68	5.96
T4 20%	5.82	6.14	5.18	5.89	5.82
T5 25%	5.50	5.39	5.11	5.43	5.57
Mean	5.72	5.91	5.27	5.59	5.83
SE	0.131	0.126	0.127	0.124	0.115
LS	N.S	N.S	N.S	N.S	N.S

* The same letter mean on the row indicates no significance (P<0.05).
* SE: Standard Errors

The effect of the addition of different levels of hump fat to beef burgers is presented in Table (2). The results showed that T2 (10% hump fat) showed the highest acceptability score with no significant difference (P ≤ 0.05) with the other treatments, followed by T3, T4, T2, and T1, respectively. These three characteristics of meat (tenderness, juiciness, and flavour) are greatly influenced by various factors, such as the animal (breed, sex, age), meat production activities (feeding, transporting, and slaughtering conditions), and processing (storing time/temperature condition) (Liu et al., 2003).
Treatment A (control) received the highest scores in flavour and overall acceptability, while treatment C received the highest scores In colour and tenderness while in juiciness T.D. Treatment E received the lowest scores of all the treatments, which were generally acceptable by the panel. There were no significant differences (P<0.05) between all the primeless treatments. Raw meat has little aroma, but meat flavour is developed because of many compounds produced in post-mortem muscle (Toldrá, 2002). Park et al. (1989) reported that a reduction in fat content in frankfurters results in decreased juiciness. Beef flavour can vary significantly due to a number of factors ranging from breed type to cattle diets or even meat processing/ageing techniques (Montgomery & Leheska, 2008). Overall acceptability, as evaluated by consumers, is a mixture of flavour and tenderness scores and other sensations that consumers perceive when they taste meat lamb samples. Overall acceptability was highly correlated with flavour and tenderness. These attributes are affected by fatty acid composition. This parameter differs among production systems (Sanudo et al., 2000) and by the cultural background and culinary habits since the kind of meat that consumers are used to eating is generally evaluated with higher scores.

Conclusion

Sensory evaluation showed that tenderness increased with the increase in the level of camel hump fat, while colour was not affected significantly by adding camel hump fat. On the other hand, flavour, juiciness and total acceptability decreased by an increase in the level of camel hump fat. Camel hump fat can successfully be added to beef burgers. Studies on the effects of hump fat on the sensory evaluation of other types of processed meat products are needed.

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ID: 520

Effect of Garlic Powder and Probiotic Supplementation on Growth Performance of Broiler Chickens

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Abstract

Garlic (*Allium sativum*), known for its bioactive compounds, antimicrobial properties, and widespread availability, serves as an effective natural feed additive in broiler diets. The present study was conducted to investigate the combined effects of either (i) commercially available imported (CIGP) or (ii) locally produced (LGP) garlic powders in combination with probiotics on the performance of broiler finishers. The experimental design was a completely randomized design evaluating five (05) treatments (Control: Basal diet containing 0.1% probiotic; T1: Basal diet containing probiotic at 0.1% and CIGP at 0.025%; T2: Basal diet containing probiotic at 0.1% and LGP at 0.025%; T3: Basal diet containing probiotic at 0.05% and CIGP at 0.025%; T4: Basal diet containing probiotic at 0.05% and LGP at 0.025%). A total of 150, 21-day-old, unsexed Indian River broiler chickens (BW±SD: 1096±46 g) were assigned randomly into five (05) treatments. Each treatment had two (02) replicates (15 birds/replicate). Proximate composition and gross energy (GE) content of both garlic powders and treatment diets were evaluated. Performance was also assessed. The LGP had higher crude protein (CP), crude fiber (CF), nitrogen-free extract (NFE), and GE than CIGP ($P<0.05$). The moisture, CP, ether extract (EE), ash, and NFE across the treatment diets were similar ($P>0.05$). The birds fed T1, T2, T3, and T4 diets showed comparatively a higher feed intake (FI), body weight gain (BWG), and lower feed conversion ratio (FCR) (21-28 d) than those fed the control diet ($P<0.05$). The broilers fed garlic-incorporated diets reduced FCR ($P<0.05$) over the period tested. The local garlic when combined with probiotic at a rate of 0.05% resulted the least production cost. Overall, the present study concluded that inclusion of LGP in combination with probiotic supplementation improves the performance of broiler finishers.

Key Words: *Broiler finisher, Garlic powder, Growth performance, Indian River, Probiotics*

ID: 521

Effect of Paddy Straw and Wood Shavings as Alternative Bedding Materials for Broiler Chickens

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Abstract

Litter materials play a crucial role in optimizing broiler performance, welfare, and environmental sustainability within the poultry industry. This study aimed to assess the effect of paddy husk (PH), wood shavings (WS) and paddy straw (PS) as alternative litter materials for performance of broilers. The experiment was conducted in a completely randomized design (CRD) evaluating three litter materials (paddy husk: PH, WS and PS). A total of 72, 14-day old Indian River (IR) broilers were weighed (540.55±23 g) and assigned randomly to three (03) treatments. Each treatment was replicated two (02) times (12 birds/replicate). Performance of birds was recorded weekly for the period of 14-35 days. Litter material had no effect (P>0.05) on the feed intake, body weight gain, feed conversion ratio and mortality of broilers. The litter material did not have any influence (P>0.05) on the dressing percentage (DP%) of broilers. The present study demonstrates that the tested litter materials has no effect on the performance, DP% in IR broiler chickens.

Key Words: *Broiler, Litter, Paddy husk,Paddy straw, Wood shavings, Growth performance*

ID: 522

Enrichmet of cakes with elderberry extract : Effects of different formulations on bioactive properties and cake quality*

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Abstract

Cake varieties differ due to formulation and production methods. Numerous studies have focused on enhancing the bioactive properties of bakery products by adding various fruit extracts. However, due to variations in formulations, significantly different results particularly in terms of bioaccessibility are obtained. In this study, elderberry (Sambucus nigra L.) (EB), a berry known for its high antioxidant capacity due to its phenolics, was used in the powdered extract form to enrich cakes. The effect of different cake formulations on the *in vitro* bioaccessibility of EB extract was investigated to determine the type of cake that provides the highest bioaccessibility of EB extract. The powdered extract was added 2% to four formulations: foam-type (sponge cake), cream-type (pound cake), a mix of foam and cream type (chiffon cake), and the AACC cake formulation. Quality characteristics of the cakes (baking loss, color, texture) and batter viscosity were evaluated. Changes in antioxidant capacity were examined using total phenolic content, total antioxidant capacity, and *in vitro* digestion model. Control cakes without extract were also produced for each formulation and analyzed. The highest baking loss, lowest batter viscosity, and lowest cake hardness were observed in chiffon cake ($p<0.05$). While no significant difference was found in crumb color change (ΔE) ($p>0.05$) , chiffon cake showed the least crust color change (16.28) ($p<0.05$). When the pre-digestion samples were compared with their control samples, the sponge cake showed higher total phenolic content and antioxidant activity (ABTS and CUPRAC) than the other formulations ($p<0.05$). However, after intestinal digestion, except for ABTS, chiffon cake exhibited significantly higher antioxidant activity (CUPRAC: 527.83 mg TE/100g; FRAP: 186.5 mg TE/100g), total phenolic content (165.59 mg GAE/100g), and bioaccessibility index (138.82%–230.82%) compared to the other formulations ($p<0.05$). Findings indicate that ıncorporating elderberry extract into chiffon cake more effectively enhances bioactive properties without affecting quality.

Key Words: *In vitro bioaccessibility, total phenolic content, antioxidant capacity, texture, viscosity*

Keklerin kara mürver ekstraktı ile zenginleştirilmesi: Farklı formülasyonların biyoaktif özellikler ve kek kalitesi üzerine etkisi*

Özet

Kek, formülasyondaki ve üretim şekillerindeki farklılıklardan dolayı değişik çeşitlerde (krema veya köpük tipi gibi) üretilebilmektedir. Farklı meyve ekstraklarının fırıncılık ürünlerine ilavesi ile bu ürünlerin biyoaktif özelliklerini artırmaya yönelik çok sayıda çalışma mevcuttur. Fakat kullanılan formülasyonlardaki farklılıklardan dolayı, özellikle biyoerişebilirlikleri açısından çok farklı sonuçlar alınmaktadır. Bu çalışmada, içerdiği fenolik bileşikler sayesinde yüksek antioksidan kapasiteye sahip üzümsü meyvelerden biri olan "kara mürver" (*Sambucus nigra* L.) meyvesi (KMM), toz ekstrakt şeklinde keklerin antioksidanlarca zenginleştirilmesinde kullanılmıştır. KMM ekstraktının *in-vitro* biyoerişebilirliğinde farklı kek formülasyonlarının etkisi araştırılmıştır ve en yüksek KMM biyoerişebilirliğinin elde edildiği kek tipinin belirlenmesi amaçlanmıştır. Toz ekstrakt; köpük tipi (sponge kek), krema tipi (pound kek), köpük tipi+krema tipi (şifon kek) formülasyonları ve standart AACC kek formülasyonuna %2 olarak eşit oranda eklenmiştir. Üretimi yapılan keklerin bazı kalite özellikleri (pişme kaybı, renk ve tekstür) ve kek hamuru viskozitesi incelenmiştir. Ayrıca biyoaktif özellikleri (toplam fenolik madde ve toplam antioksidan kapasite) ve *in vitro* sindirim modeli kullanılarak antioksidan kapasitelerindeki değişiklikler araştırılmıştır. Her bir formülasyonun ekstraktsız kontrol kekleri de üretilip aynı analizler gerçekleştirilmiştir. En yüksek pişme kaybı, en düşük hamur viskozitesi ve en düşük kek sertliği şifon kekte görülmüştür ($p<0,05$). Formülasyonların kendı arasında iç (gözenek) renk değişimi (ΔE) anlamlı bulunmazken ($p>0,05$) dış (kabuk) ΔE değeri en az bulunan şifon kek olmuştur (16,28) ($p<0,05$). *In- vitro* sindirim öncesi örnekler kontrolu ile kıyaslandığında sponge kekin diğer formülasyonlardan daha yüksek toplam fenolik madde ve antioksidan aktiviteye (ABTS ve CUPRAC) sahip olduğu görülmüştür ($p<0,05$). Ancak bağırsak sindirimi sonrası şifon kek örneklerinde ABTS dışında antioksidan aktivite (CUPRAC 527,83 mg TE/100g FRAP 186,5 mg TE/100g) toplam fenolik miktarı (165,59 mg GAE/100 g) ve biyoerişilebilirlik indeksi (%138,82 - 230,82) diğer formülasyonlardan önemli düzeyde yüksek bulunmuştur ($p<0,05$). Elde edilen sonuçlara göre, kara mürver ekstraktının şifon kek formülasyonunda kullanılmasının, kek kalitesini olumsuz etkilemeden, biyoaktif özelliklerinin geliştirilmesinde daha etkili olduğu tespit edilmiştir.

Anahtar Kelimeler: *In vitro biyoerişebilirlik, toplam fenolik madde, antioksidan kapasite, tekstür, viskozite*

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ID: 523

Scanning Electron Microscopy (SEM) Technique on Honey Bee (*Apis mellifera*) Taxonomic Studies

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Abstract

Taxonomic zoology, a sub-discipline of biology, encompasses the rules governing the classification of animals and integrates insights from various scientific fields. While traditional taxonomy relies primarily on morphological character analysis, modern approaches incorporate geometric morphometrics, population genetics, molecular biology, and bioinformatics. Currently, honey bee diversity is represented by more than 29 subspecies, although this number is still controversial among researchers. Micro-diversitys in diagnostic characters within honey bees have often been overlooked. From this perspective, SEM offers a rapid analytical method for distinguishing between subspecies or ecotypes. This study aims to assess the applicability of SEM morphological analysis in characterizing honey bee biodiversity. Specifically, it evaluates the maxillary palpus segment as a supporting character for both classical and modern taxonomic methodologies.

Keywords: *SEM, Apis mellifera, Biodiversity, Maxillary palpus, Morphology*

ID: 525

Perceived Impact of Tea Farming on Livelihoods of Smallholder Farmers in Panchagarh District

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Abstract

The main objective of the study was to assess the perceived impact of tea farming on livelihoods of the smallholder tea growers. The research was conducted in the Tetulia upazila under Panchagarh district. A total of 550 farmers constituted the population of the study, and 118 small tea growers were selected as samples of the study following simple random sampling techniques. An interview schedule was used for data collection, and data was collected from 28 August to 12 October 2023. Perceived impact on livelihood of the small tea growers were assessed based on a five-point Likert scale. In contrast, both Pearson's product-moment correlation coefficient (r) and multiple linear regressions were performed to determine the relationships, influence and contribution of the selected characteristics to perceived impact of tea farming on livelihood of smallholder farmers. The results of the study showed that tea farming had a medium perceived impact on livelihood of the 67.8 percent farmers. The selected characteristics of the farmers such as education status, farm size, tea cultivating area, income from tea farming, innovativeness, knowledge on tea farming, and attitude towards selling price of tea leaves have significant and positive effect on perceived impact of tea farming on livelihood of the small holder tea growers. Multiple regression analysis revealed that the whole model explained 63.9 percent of the total variation in the perceived impact of tea farming on livelihood of the small holder tea growers. Education status, innovativeness, knowledge on tea farming, and attitude towards selling price of tea leaves showed significant positive contributions to the perceived impact of tea farming.

Key Words: *Livelihood, Smallholder tea growers, Percieved impact, Tea farmers, Panchagarh district*

ID: 526

Lamiaceae (ballıbabagiller)Türlerinin Peyzaj Tasarımında kullanım Olanakları

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ÖZ

Küresel ısınma ile artan sıcaklık, azalan su kaynakları peyzaj tasarımında kullanılan bitki türlerinin seçiminde sınırlama getirmiştir. Bu çalışmada, belirlenen koşullarda uygun olabilecek, kekik *(Thymus sp.)* ve adaçayı *(Salvia sp.)* türlerinin botanik özellikleri, ekolojik gereksinimleri, yetiştirme teknikleri ve peyzaj tasarım çalışmalarında kullanımını incelenmektedir. Her iki bitki de tıbbi ve aromatik bitkiler arasında önemli bir yere sahip olup sağlık, kozmetik ve gıda sektörlerinde geniş kullanım alanına sahiptir. Ayrıca, ekolojiye uygun sürdürülebilir peyzaj tasarımlarında fazlasıyla tercih edilmektedir. Kekik türleri, özellikle Akdeniz iklimine adapte olmuş olup, iyi drene edilen, kireçli ve kumlu-tınlı topraklarda başarılı şekilde yetiştirilmektedir. Uçucu yağ içeriği açısından yüksek değere sahip olan kekik, antimikrobiyal, antioksidan ve antiinflamatuvar özellikleriyle öne çıkmaktadır. Adaçayı ise ılıman iklim koşullarına uyum sağlayan ve toprak seçiciliği düşük olan bir bitkidir. Bununla birlikte, adaçayı bitkisi aynı zamanda antioksidan ve iltihap önleyici bileşenleri sayesinde bağışıklık sistemini destekleyici etkileriyle bilinmektedir. Ayrıca, adaçayının beyin fonksiyonlarını destekleyici etkileri olduğu, hafızayı güçlendirdiği ve sinir sistemine olumlu katkılar sunduğu belirlenmiştir. Kekik *(Thymus sp.)* ve adaçayı *(Salvia sp.)* türlerinin polinatörleri çekerek biyolojik çeşitliliği desteklediği ve sürdürülebilir tarım için önemli olduğu belirtilmektedir. Aynı zamanda, *Thymus* sp. ve *Salvia sp.* türlerinin kuraklığa dayanıklı olması, xeriscaping uygulamalarında avantaj sağlamaktadır. Bu bitki türlerinin doğal zararlılara karşı dirençli olması, kimyasal pestisit kullanımını azaltarak ekolojik tarım uygulamalarına katkı sunmaktadır. Sonuç olarak, kekik ve adaçayı türleri tıbbi, aromatik ve peyzaj uygulamaları açısından büyük potansiyele sahiptir. Ekonomik değeri yüksek bu bitkilerin, ekolojik sürdürülebilirlik ve çevresel iyileştirme açısından da önemli katkılar sunduğu görülmektedir. Ayrıca, iklim değişikliğine bağlı olarak artan kuraklık koşullarında, su kullanımını optimize eden bitkilerin seçilmesi, gelecekte tarımsal üretimde ve peyzaj tasarımlarında önemli bir strateji olacaktır. Çalışmamızda, değerlendirilecek bitkilerle oluşturulmuş peyzaj alanlarında Sketchup, Lumion programlarında titizlikle detaylı modelleme yapılarak görseller oluşturulacaktır.

Anahtar Kelimeler: *Kekik, Adaçayı, Ekoloji, Yetiştirme Teknikleri, Peyzaj Kullanımı, Tıbbi ve Aromatik Bitkiler, Sürdürülebilir Tarım, Xeriscape*

ID: 527

Effect of Glycyrrhizic Acid on Growth Performance in Meagre (*Argyrosomus regius*) Juveniles

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Abstract

The aquaculture sector is developing in both Mediterranean countries and in our country in parallel with the developing technology. However, the increasing amount of production has also caused new problems. Especially in terms of fish health and product quality improvement, new additives are being defined in the recent days. Glycyrrhizic acid has recently started to be widely used both in human health and in agriculture and aquaculture. n this study, the effects of glycyrrhizic acid on growth as well as acid and alkaline protease activity in juveniles of meagre (*Argyrosomus re*gius), one of the potential new species produced in our country, were investigated. In this study which lasted for 60 days and 3 replicates, total 180 meagre juveniles with an average length of 8.38±0.23 cm and weight of 9.86±0.29 g were fed with 2 different diets in 2 groups as control (0 ml.kg^{-1} GA) and experimental group (4 ml.kg^{-1} GA). At the end of the experiment, significant differences were found in both feed conversion ratio (FCR) and specific growth rate (SGR) ($p<0.01$) and acid and alkaline protease activities ($p<0.05$) obtained from the group to which 4 ml.kg^{-1} GA was added. However, no difference was observed between the experimental groups in terms of survival rate ($p>0.05$). As a result, it was determined that the addition of 4 ml.kg^{-1} GA to the feed provided significant positive results in growth performance, enzymatic activity and nutritional parameters in meagre culture.
Key Words: *Glycyrrhizic acid, Meagre, Argyrosomus regius, Growth performance, Digestive enzymes*

Farklı Oranlarda Glisirizik Asit Kullanımının Sarıağız (*Argyrosomus regius*) Juvenillerinde Büyüme Parametrelerine Olan Etkileri

Özet

Akuakültür sektörü, gelişen teknoloji ile paralel olarak Akdeniz ülkeleri ve ülkemizde gelişim göstermektedir. Ancak artan üretim miktarı da beraberinde yeni sorunları gündeme getirmiştir. Özellikle balık sağlığı ve ürün kalitesinin geliştirlşmesi açısından her geçen gün yeni katkı maddeleri tanımlanmaktadır. Glisirizik asitte (GA) son yıllarda hem insan sağlığı hemde tarım ve akuakültürde kullanımı yaygınlaşmaya başlamıştır. Bu çalışmada ülkemizde üretilen potansiyel yeni türlerin başında gelen sarıağız (*Argyrosomus regius*) juvenillerinde glisirizik asidin büyümenin yanında asit ve alkalin proteaz aktivitesine olan etkileri incelenmiştir. Toplamda 60 gün ve 3 tekrarlı süren denemelerde ortalama 8,38±0,23 cm boy ve 9,86±0,29 g ağırlığa sahip 180 adet sarıağız yavrusu 2 grupta kontrol (0 ml.kg^{-1} GA) ve deneme grubu (4 ml.kg^{-1} GA) olmak üzere 2 farklı diyetle beslenmiştir. Deneme sonunda 4 ml.kg^{-1} GA eklenen gruptan elde edilen hem yem dönüşüm oranı (FCR) ve spesifik büyüme oranı (SGR) ($p<0.01$) hem de asit ve alkalin proteaz aktivitelerinde önemli farklılıklar tespit edilmiştir ($p<0.05$). Bununla birlikte yaşama oranı oranı açısından deneme grupları açısından bir farklılık gözlenmemiştir ($p>0.05$). Sonuç olarak yeme 4 ml.kg^{-1} GA eklenmesinin sarıağız kültüründe başta büyüme performansı olmak üzere enzimatik aktivitede ve besleme parametlerinde de önemli olumlu sonuçlar sağladığı tespit edilmiştir.

Anahtar Kelimeler: *Glisirizik asit, Sarıazğız, Argyrosomus regius, Büyüme performansı, Sindirim enzimleri.*

ID: 528

Phytochemical Analysis of Selected Medicinal Plants Belonging to Family Fabaceae

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Abstract

Many plants from the Fabaceae family have long been used for their pharmacological and protective properties, gaining popularity for commercial and academic purposes. Therefore, a study was conducted to evaluate the phytochemical potential of eight high-value species from the Bangladesh Agricultural University Botanical Garden namely: Lojjaboti (*Mimosa pudica* L.), Krisnachura (*Delonix regia* (Bojer ex Hook.) Raf.), Edanchi (*Senna tora* (L.) Roxb.), Kolka-sunda (*Senna occidentalis* (L.) Link), Koroi (*Albizia lebbeck* (L.) Benth.), Karanja (*Pongamia pinnata* (L.) Pierre), Shingra (*Cynometra ramiflora* L.) and Rati (*Abrus precatorius* L.). Total phenolic content (TPC), total flavonoid content (TFC), total antioxidant capacity (TAC) and major pigments (chlorophyll a and b, total carotenoids) were measured using standard protocols. The findings indicated that *S. tora* had the highest TPC (15.999 mg GAE/g DW) and total antioxidant capacity (TAC) with 8.25 mg AA/g FW, while *A. lebbeck* exhibited maximum TFC (27 mg QUE/g DW). *M. pudica* had the highest levels of chlorophyll a and total chlorophyll (a+b), with 1.58 mg/g FW and 2.62 mg/g FW, respectively. *D. regia* leaf showed the highest amount of chlorophyll b (1.81mg/g FW) and carotenoids content (4.52 mg/g FW). Significant positive relationships were found between different phytochemicals such as TPC and TAC; total chlorophyll and total carotenoids, while a non-significant relationship was found between TAC and other pigments. The species were categorized into three clusters and the phytochemicals were grouped into two groups. Variations were observed among all the species, but *S. tora* and *M. pudica* were placed into cluser-1 containing highest phytochemical contents while *C. ramiflora* showed lowest phytochemicals which placed into cluser-3 and remaining others were in cluster-2. These findings suggested the potential of these plants as promising sources for medicine development, with their bioactivity supporting their strong recommendation for their use in traditional medicine.

Keywords: *Fabaceae; Phytochemicals; Medicinal Plants; Total Phenolic Content; Total Flavonoid Content; Total Antioxidant Capacity.*

ID: 529

Reduction of Live Feed in the Early Life of Sea Bream (*Sparus aurata*, L.) Larviculture: Effects on Enzymatic and Histomorphological Development

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Abstract

During the recent years, increasing production costs have caused alternative feeding strategies to reduce costs and increase sustainability in marine fish culture. The fact that live feed production requires high labour force and application has led producers to limitations and the use of new feed additives in this field. In this study, the enzymatic and histological effects of gradual reduction of rotifer (*Brachionus plicatilis*), which is a live food commonly used in the feeding of gilthead sea bream (*Sparus au*rata) larvae produced intensively in our country, were investigated. Within the scope of the experiment, a total of 4 experimental groups, one of which was a control group and the remaining three were experimental groups, were designed with three replications. While the amount of rotifer given to the bream larvae in the control group was not decreased, the other experimental groups were reduced by 25, 50 and 75%, respectively. Natura Pro®, a commercial product, was used instead of the reduced amount of live food. At the end of the experiment, larvae fed with 25 and 50% rotifer reduction had similar growth performance, total protease activity and gastrointestinal histomorphology with the control group receiving full rotifer supplementation and there was no statistical difference ($p>0.05$). However, 75% reduction in rotifer administration resulted in significantly lower growth rate, enzymatic activity and developmental disorders in gastrointestinal histomorphology and higher mortality, suggesting that rotifer supplementation constitutes a critical threshold for larval health and development ($p<0.05$). As a result, it was determined that it is economical and meaningful to reduce the live feed by 25% to 50% with the support of additives added by considering the nutritional requirements of the larvae in the early period in sea bream larviculture.

Key Words: *Sea bream, Sparus aurata, Live food, Digestive enzymes, Histology.*

Çipura (*Sparus aurata*, L.) Larva Yetiştiriciliğinde Erken Dönemde Canlı Yem Kullanımının Azaltılması: Enzimatik ve Histomorfolojik Gelişime Olan Etkileri

Özet

Son yıllarda artan üretim maliyetleri deniz balığı yetiştiriciliğinde maliyetleri düşürmeye ve sürdürülebilirliği artırmaya yönelik alternatif beslenme stratejilerini gündeme getirmiştir. Canlı yem üretiminin yüksek iş gücü ve uygulama gerektirmesi üreticileri bu alanda kısıtlamalara ve yeni katkı maddelerinin kullanımına yönlendirmiştir. Bu çalışmada, ülkemizde yoğun olarak üretimi yapılan çipura (*Sparus aurata*) larvalarının beslenmesinde yaygın olarak kullanılan canlı yem olan rotiferin (*Brachionus plicatilis*) kademeli olarak azaltılmasının enzimatik ve histolojik açıdan etkileri incelenmiştir. Deneme kapsamında biri kontrol kalan üçü deneme grubu olmak üzere toplamda 4 deneme grubu üç tekrarlı olarak tasarlanmış ve kontrol grubundaki çipura larvalarına verilen rotifer miktarı azaltılmaz iken diğer deneme gruplarında sırasıyla %25, %50 ve %75 oranlarında azaltılma yapılmıştır. Azaltılan oranda yerine ticari bir ürün olan Natura Pro® kullanılmıştır. Deneme sonunda, %25 ve %50 rotifer azaltımı ile beslenen larvaların, tam rotifer takviyesi alan kontrol grubuyla benzer büyüme performansı, total proteaz aktivitesi ve gastrointestinal histomorfolojiye sahip olduğunu ve istatistiksel farklılık olmadığını göstermiştir ($p>0.05$). Ancak, rotifer kullanımının %75 oranında azaltılması, önemli şekilde düşük büyüme hızı, enzimatik aktivite ve gastrointestinal histomorfolojide gelişim bozuklukları ile daha yüksek mortaliteye yol açmış ve rotifer takviyesinin larva sağlığı ve gelişimi için kritik bir eşik oluşturduğunu ortaya koymuştur ($p<0.05$). Sonuç olarak çipura larva kültüründe erken dönemde larvanın besinsel gereksinimi göz önünde bulundurularak eklenen katkı maddeleri desteği ile canlı yemin %25 ile %50 oranlarında azaltılmasının ekonomik ve anlamlı olduğu tespit edilmiştir.

Anahtar Kelimeler: *Çipura, Sparus aurata, Canlı yem, Sindirim enzimleri, Histoloji.*

ID: 530

Effect of Needle Micro-Perforation Pretreatment as an Alternative to Alkaline Dipping Solution in Grape Drying on Bioactive Compounds

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Abstract

Grape (*Vitis sp.*) is widely consumed and cultivated globally. In addition to being consumed fresh as wine, juice or dried fruit. It is known for its bioactive compounds, such as flavonoids, polyphenols, anthocyanins, and tannins, which provide health benefits, including antioxidant, anti-inflammatory, and cardioprotective effects. However, grapes are highly susceptible to microbial spoilage due to their high water content, limiting their shelf life. Drying is one of the most common methods used to extend grape shelf life. Pretreatments before drying facilitate moisture removal, accelerating the drying process and preserving nutrients, This study investigates the potential of needle micro-perforation (0.5 mm, 1 mm, and 1.5 mm needle lengths) as an alternative to the widely used dipping method. The total phenolic content, antioxidant capacity (DPPH and CUPRAC), and anthocyanin content of Kavacık grapes (*Vitis vinifera L.* "Alphonse Lavallée" variety) were analyzed. Pretreated grapes were dried using static and convective methods at 60°C, 70°C, and 80°C, and their bioactive compounds were evaluated. Results showed that different pretreatments had varying effects on bioactive compounds. Needle micro-perforation was as effective as the dipping method in preserving total phenolics, antioxidants, and anthocyanins. In static drying, the total phenolic content of samples with needle micro-perforation was approximately 250 mg per 100 g of dry matter higher than that of samples with the dipping treatment. In convective drying, this difference increased to about 400 mg per 100 g of dry matter. Similarly, antioxidant capacity was about 10 µmol Trolox equivalent per gram of dry matter higher in needle micro-perforation samples under static drying and 20 µmol higher under convective drying. In conclusion, needle micro-perforation effectively preserves bioactive compounds and can be considered an alternative to the dipping method.

Key Words: *Kavacık grape, pretreatment, needle micro-perforation, total phenolic content, antioxidant capacity.*

Introduction

Grapes are among the most widely cultivated fruits globally, with an annual production of around 75 million tons (Srivastava et al., 2021). Data from the 2019–2020 period indicates that China leads in grape production, followed by India and Turkey (Sabra et al., 2021; Topalović et al., 2020). According to the Institute of Agricultural Economics and Policy Development, Turkey produced about 3.8 million tons of grapes during the 2023/2024 season, with Manisa being the leading region. Grapes are consumed fresh, used in wine production and processed into products like fruit juice, jam, seed extract, and grape seed oil (Sabra et al., 2021; Srivastava et al., 2021). Approximately 50% of global grape production is allocated to wine, one-third is consumed as fresh fruit, and the remain is used for drying (Srivastava et al., 2021). Grape cultivation depends on climate, disease resistance, fruit color, taste, and whether the variety is seeded or seedless (Sabra et al., 2021). There are between 8,000 and 10,000 *V. vinifera* grape varieties used for commercial purposes (Sabra et al., 2021). Grapes consist of skin, seeds, and pulp. They are rich in bioactive compounds, especially polyphenols, which vary across fruit components (Zhou et al., 2022). These include flavonoids, phenolic acids, and anthocyanins (Kupe et al., 2021). The concentration of these compounds varies by grape variety and is linked to health benefits. Polyphenols in grapes may help prevent cardiovascular diseases, reduce cholesterol, control blood pressure, and protect against several cancers, including breast, skin, lung, colon and prostate (Aubert & Chalot, 2018; Sabra et al., 2021; Topalović et al., 2020). Grapes are also rich in sugars and contain vitamins (A, B1, B3, C) and minerals (iron, potassium, calcium, sodium) (Kirazcı, 2022). Kavacık grapes are grown in Kavacık village in the Karabağlar district of Izmir, Turkey, from the *Vitis vinifera L. 'Alphonse Lavallée'* variety. They are known for their high phenolic content and have received geographical indication as a table grape (Ministry of Culture and Tourism, 2023). Studies confirm the high polyphenol and bioactive compound content of this variety (Aubert & Chalot, 2018). Besides fresh consumption, Kavacık grapes are used to produce molasses and Turkish delight.

Due to their high water content, grapes are susceptible to spoilage from microbial and chemical reactions. Drying is commonly used to extend shelf life by reducing water content and water activity, slowing microbial growth and chemical degradation (Adeyeye et al., 2022). Drying is simple, cost-effective and reduces weight and volume, lowering packaging. Transportation, and storage costs (Ozkan et al., 2022). The drying method affects processing time, energy use and product quality (Ozkan et al., 2022). Hot air drying (HAD) is a faster alternative to sun drying. It offers benefits like reduced drying time, ease of use, low operational costs and better preservation of food safety and quality (Senadeera et al., 2020). Cabinet dryers, commonly used in HAD, prevent microbial spoilage, improving product quality (Yasmin et al., 2022). However, uneven air distribution in these dryers can be addressed by modifying fan placement or using dual fans (Günaydın et al., 2022). Hot air drying of grapes is a widely studied topic in the literature, Hermassi et al. (2017) investigated the drying of seedless Sultani grapes using a hot air dryer at various temperatures, evaluating moisture loss, shrinkage and drying rates through mathematical models. They found that moisture diffusivity increased with temperature, ranging from 3.56×10^{-10} to 12.6×10^{-10} m^2/s, and calculated an activation energy of 57.76 kJ/mol. Similarly, Shafiq et al. (2022) studied seedless grapes using different pretreatments (K_2CO_3 + ethyl oleate, olive oil, hot water and control) and three drying methods (cabinet-type tray dryer, sun tunnel, and open-air drying). The results showed that grapes pretreated with K_2CO_3 + ethyl oleate and dried in a tray dryer had the shortest drying time (26.08 h), with a lighter yellow-green appearance and softer texture.

Drying is energy-intensive and time-consuming, leading to the use of pretreatments to enhance drying efficiency, reduce energy costs and preserve food quality (Gavahian et al., 2024). Pretreatments can be physical (thermal and non-thermal) or chemical (Bassey et al., 2021; Deng et al., 2019). Chemical pretreatments involve immersing the product in solutions or exposing it to gases (Deng et al., 2019). Alkaline dipping in a potash solution is a common chemical pretreatment for grape drying, typically containing 5% potassium carbonate and 1–2% olive oil (Çoban & Abuşka, 2024). Potassium carbonate removes the waxy layer on the grape skin, facilitating moisture loss and shortening drying time (Carranza-Concha et al., 2012). This method preserves color and reduces drying time in seedless and black grapes (Doymaz, 2006; Shafiq et al., 2022). However, concerns about chemicals in food and water safety have increased interest in sustainable, chemical-free methods (Deng et al., 2019). Physical pretreatments, such as ultrasonic field, microwave, pulsed electic field enhance drying efficiency without chemicals (Bassey et al., 2021; Deng et al., 2019). Needle micro-perforation, which is a physical pretratment, creates small pores in the fruit peel, increasing diffusion and accelerating moisture removal. This method is more effective than some chemical methods in reducing drying time (Jazini & Hatamipour, 2010; Mabellini et al., 2013). Olives, plums, and cherries benefit from this technique, as the waxy layer on their skin acts as a barrier to moisture removal (Mabellini et al., 2012). In a study on olives, different pretreatments such as perforation with a metal brush, blanching, a combination of perforation and blanching and perforation followed by immersion in brine were applied before hot air drying. It was found that perforation had a positive effect on the drying process, enhancing moisture loss and improving overall drying efficiency (Gambella, 2000).

In this study, Kavacık grapes were dried at 60, 70, and 80°C using static and convective dryers. Needle micro-perforation and alkaline dipping pretreatments were applied, with needle lengths of 0.5, 1.0, and 1.5 mm tested. The aim of this study is to determine and evaluate the effects of needle micro-perforation pretreatment on bioactive compounds of Kavacık grapes by comparing with alkaline dipping pretreatment.

Materials and Methods

Materials

Kavacık village (Karabağlar, Izmir) sourced *Alphonse Lavallée (Vitis vinifera L.)* grapes were harvested at optimum ripeness. To reduce fungal contamination, grapes were immersed in 5% vinegar for 15 minutes, rinsed with water, air-dried, and stored in 500 g polyethylene bags at 4 °C for up to 15 days. Average berry diameter and length were 25.23 ± 3.80 mm and 25.99 ± 4.92 mm. Respectively, with a mean weight of 8.90 ± 0.48 g. Initial moisture content was 4.04 ± 0.02 kg water/kg dry matter (AOAC method, 100 °C). Grapes were divided into two pretreatment groups as alkaline dipping (control) and needle micro-perforation.

Pretreatments

In this study, needle pretreatment was compared with the industry-standard alkaline dipping method, which is widely used for grape drying. Accordingly, the control group (DG) was prepared for drying by immersion in an alkaline solution containing 5% (v/v) potassium carbonate (K_2CO_3) and 1% (v/v) extra virgin olive oil at 25 °C for 2 minutes, following the method described by Doymaz and Altıner (2012). Needle micro-perforated grapes (MG0.5, MG1.0, and MG1.5) were punctured using micro-perforators with the same number of needles but varying needle lengths: 0.5 mm for MG0.5, 1.0 mm for MG1.0 and 1.5 mm for MG1.5. These lengths were selected to be shorter than, equal to or longer than the average skin thickness of the grapes.

Drying Process

Grape samples (approximately 25 g per group), including the needle micro-perforated (MG0.5, MG1.0, MG1.5) samples and the alkaline-dipped control group (DG), were dried at 60, 70, and 80 °C using a static cabinet dryer and a convective hot air dryer. Both systems featured temperature control to ensure consistent thermal conditions throughout the drying process. The airflow velocity in the convective dryer was measured as approximately 2.5 m/s using a mini anemometer (UT363, Uni-T, China). The drying process continued until the sample weights reached a final moisture content of 0.24 kg water/kg dry matter.

Bioctive Compound Analysis

Total Phenolic Content (TPC)

The total phenolic content was determined using a modified version of the method outlined by Akbaş et al. (2017). For this analysis, extracts were prepared from both dried and fresh grape samples. For the dried grape extracts, approximately 2–3 grams of dried grapes were weighed and immersed in a sealed container with a solvent at a ratio of 1:10 (dried grape:solvent). The solvent comprised 80% methanol, 19.9% distilled water and 0.1% hydrochloric acid (HCl). The samples were incubated at +4 °C for 24 hours. Similarly, for the fresh grape extracts, approximately 10 grams of fresh grapes were weighed and combined with the same solvent at a 1:10 ratio. Following extraction, the grapes were ground in a mortar and filtered. Similarly, for the fresh grape extracts, approximately 10 grams of fresh grapes were weighed and combined with the same solvent at a 1:10 ratio.

For the phenolic content analysis, 0.5 ml of the extract was mixed with 2.5 ml of 0.2 N Folin–Ciocalteu reagent, vortexed, and allowed to incubate in the dark for 3 minutes. Following this, 2 ml of 7.5% sodium carbonate solution was added and, the mixture was vortexed again and incubated for 30 minutes. After the incubation period, absorbance was measured at 760 nm using a UV-Vis spectrophotometer (PG Instruments. United Kingdom). Calibration was performed using gallic acid standard solutions of varying concentrations (10, 20, 40, 50, 80, and 100 mg/ml). The same procedure was applied to each standard solution, and a standard curve was generated from the absorbance values. The total phenolic content was then calculated and expressed as milligrams of gallic acid equivalent (mg GAE) per 100 grams of dry matter.

Total Antioxidant Capacity

The total antioxidant capacity was evaluated using the DPPH (2.2-Diphenyl-1-picrylhydrazyl) radical scavenging method, as described by Özkan (2022) with some modifications. In this procedure, 0.1 mL of the grape extract was added to a test tube, followed by 4.9 mL of 0.1 mM DPPH solution. The mixture was vortexed and incubated in the dark at room temperature for 20 minutes. Absorbance of the DPPH solution was measured at 517 nm using a UV-Vis spectrophotometer (PG Instruments. United Kingdom). Calibration was performed with Trolox standard solutions at concentrations of 100, 500, 1000, 1500, 2000, and 2500 µmol/L, following the same procedure. A standard calibration curve was generated based on the absorbance values, and the total antioxidant capacity was calculated and expressed as milligrams of Trolox Equivalent (TE) per gram of dry matter.

The total antioxidant capacity was also measured using the CUPRAC (Cupric Ion Reducing Antioxidant Capacity) method, following the modified procedure by Özkan (2022). In this method, 0.1 mL of grape extract (fresh or dried) was transferred to a tube, and sequentially, 1 mL of each of the following solutions was added: $CuCl_2$ (10 mM), neocuproine (7.5 mM, alcoholic), NH_4Ac buffer (1 M. pH 7.0), and distilled water. The mixture was incubated in the dark at room temperature for 1 hour. Absorbance was then measured at 450 nm using a UV-Vis spectrophotometer (PG Instruments, United Kingdom). For calibration, Trolox standard solutions with concentrations of 1000, 1500, 2000, 2500, 3000, and 4000 µmol/L were prepared, and the CUPRAC method was applied for each. A calibration curve was constructed based on the absorbance values and the antioxidant capacity was calculated and expressed as milligrams of Trolox Equivalent (TE) per gram of dry matter.

Total Anthocyanin Content (TAC)

The total anthocyanin content was measured using the pH differential method as described by Özkan (2022). In this method, 0.025 M potassium chloride (KCl) and 0.4 M sodium acetate ($CH_3COONa \cdot 3H_2O$) solutions were prepared using distilled water. For the measurement, 0.8 mL of the grape extract was mixed with 3.2 mL of the potassium chloride solution, and a second 0.8 mL of the extract was mixed with 3.2 mL of the sodium acetate solution in different test tubes. The mixtures were incubated in the dark at room temperature for 30 minutes.

Absorbance values were then recorded at 510 nm and 700 nm using a UV-Vis spectrophotometer (PG Instruments. United Kingdom).

The total anthocyanin content was calculated using Equations 1 and 2:

$$A = [\text{A510nm} - \text{A700nm}]\text{pH1.0} - [\text{A510nm} - \text{A700nm}]\text{pH4.5} \quad (1)$$

$$TA = \frac{A \times MW \times D_f \times 1000}{\varepsilon \times L} \quad (2)$$

Where A is absorbance, A510 is absorbance at 510 nm, A700 is absorbance at 700 nm, MW is molecular weight of malvidin 3-glucoside (463.3 g/mol), D_f is dilution factor, ε is molar absorption coefficient (28.000 L/mol*cm), L is optical path length of the cuvette (1 cm), The results were expressed as mg malvidin-3-glucoside per 100 g dry matter.

Statistical Analysis

In this study. the effects of alkaline dipping and needle micro-perforation pretreatments on bioctive compounds of Kavacık grape were examined using selected independent variables (needle length, drying temperature). All measurements were repeated three times, and statistical differences between pretreatments were determined using analysis of variance (ANOVA) and Tukey's post-hoc test ($P \leq 0.05$). The data are presented in tables containing the means and standard deviations of the results from the three repeated trials.

Result and Discussion

Bioactive contents of fresh grapes are given in Table 1. Total phenolic value of fresh Kavacık grape was found as 1097.97 mg GAE/100 g dw, antioxidant capacity was found as 32.49 µmol TE/g dw by DPPH method, 151.59 µmol TE/g dw by CUPRAC method and total anthocyanin content was found as 14.45 mg mlv-3-glc/100 g dw. Özkan (2022) reported the total phenolic content of the black-scented 'Isabella' grape (Vitis labrusca L. × Vitis vinifera L.), which is rich in bioactive compounds, as 1101.61±35.12 mg GAE/100 g dw. The DPPH Free Radical Scavenging Activity was reported as 34.51±1.21 µmol TE/g dw, the antioxidant activity value by the CUPRAC method was 175.82±5.35 µmol TE/g dw, and the total anthocyanin (TAC) content was 341.88±4.42 mg mlv-3-glc/100 g dw. The total phenolic content (TPC) of the Kavacık grape variety used in this study was found to be similar to that of the black-scented grape, while the TAC value was lower. This difference can be attributed to the use of different grape varieties in the studies, as well as the varying climatic and soil conditions in which the grapes were grown, leading to differences in their bioactive properties.

Table 1. Bioactive content of fresh grape.

	Fresh Grape
TPC (mg GAE/100 g dw)	1097.97 ± 168.95
Antioxidant Capacity (DPPH - µmol TE/g dw)	32.49 ± 2.01
Antioxidant Capacity (CUPRAC -µmol TE/g dw)	151.59 ± 25.99
TAC (mg mlv-3-glc/100 g dw)	14.45 ± 0.36

The bioactive contents of the samples dried with a static dryer are shown in Table 2. While the total phenolic values of dipped grapes (DG) ranged between 440.50 and 604.40 mg GAE/100 g dw, the total phenolic values of micro-perforated grapes (MG) ranged between 427.30 and 886.40 mg GAE/100 g dw. Phenolic compounds not only contribute to the color, taste, and aroma of grapes but also provide significant nutritional and health benefits (Çoklar & Akbulut, 2017). As shown in Table 2, different pretreatments applied to samples dried using a static dryer did not lead to a significant difference in the total phenolic content (TPC) ($P > 0.05$). Additionally, it was found that temperature increase did not cause a significant difference in the TPC of DG and MG0.5 samples ($P > 0.05$), but both low (60°C) and high (80°C) temperatures resulted in a significant difference in TPC for M1.0 and MG1.5 samples ($P < 0.05$). The values obtained in this study are consistent with those reported in the literature. For instance, Barbosa da Silva et al. (2023) found that the total phenolic content of BRS Vitoria grapes ranged from 340.98 to 1794.80 mg GAE/100 g dw following convective drying after ethanol and ultrasound pretreatments. In a previous study, the total phenolic content of freeze-dried and oven-dried BRS Magna grape skin was found to be 148.3 and 149.9 mg/100 g dw, respectively. The total phenolic content in this study is similar to those reported in previous studies (da Silva et al., 2020).

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Table 2. Bioactive content of dried grapes (Static dryer).

Dryer Type		TPC (mg GAE/100 g dw)			
		DG	MG0.5	MG1.0	MG1.5
Static	60°C	604.40 ± 15.6^{Aa}	427.30 ± 129.10^{Aa}	492.90 ± 25.10^{Ab}	555.70 ± 100.10^{Ab}
	70°C	644.60 ± 22.10^{Aa}	724.20 ± 111.40^{Aa}	810.70 ± 34.20^{Aa}	886.40 ± 58.90^{Aa}
	80°C	440.50 ± 109.60^{Aa}	568.90 ± 52.90^{Aa}	442.60 ± 32.10^{Ab}	533.90 ± 20.80^{Ab}
		Antioxidant Capacity (DPPH - µmol TE/g dw)			
	60°C	68.58 ± 2.91^{Aab}	77.44 ± 7.84^{Aa}	64.46 ± 0.90^{Ab}	74.20 ± 5.49^{Aa}
	70°C	60.58 ± 2.13^{Bb}	72.62 ± 0.04^{Aa}	73.17 ± 2.69^{Aa}	68.66 ± 1.68^{Aa}
	80°C	74.20 ± 0.03^{Aa}	64.62 ± 1.79^{Ba}	75.15 ± 0.04^{Aa}	62.40 ± 3.58^{Ba}
		Antioxidant Capacity (CUPRAC -µmol TE/g dw)			
	60°C	178.28 ± 8.36^{Aa}	137.22 ± 9.70^{Bb}	152.31 ± 1.19^{ABa}	147.35 ± 4.33^{Ba}
	70°C	162.66 ± 0.60^{ABa}	173.95 ± 2.24^{Aa}	148.72 ± 11.04^{Ba}	156.43 ± 1.94^{ABa}
	80°C	138.91 ± 3.73^{Ab}	140.42 ± 2.16^{Ab}	124.24 ± 5.67^{Bb}	133.53 ± 2.39^{ABb}
		TAC (mg mlv-3-glc/100 g dw)			
	60°C	65.15 ± 0.95^{Aab}	68.35 ± 4.02^{Aab}	64.37 ± 2.05^{Aa}	66.04 ± 1.89^{Aa}
	70°C	61.81 ± 0.32^{Cb}	70.51 ± 0.95^{Aa}	65.49 ± 0.47^{Ba}	68.50 ± 1.26^{ABa}
	80°C	66.83 ± 1.74^{Aa}	61.69 ± 1.74^{Ab}	63.48 ± 3.00^{Aa}	68.95 ± 1.26^{Aa}

*If means ± standard deviation within a row are shown with different capital letters, there is a statistically significant difference ($P < 0.05$).
**If means ± standard deviation within a column are shown with different lower case letters, there is a statistically significant difference ($P < 0.05$).

Antioxidants are compounds that neutralize free radicals, which are produced through various mechanisms in the human body and contribute to oxidative stress and cellular damage (Kunter & Keskin, 2019). Antioxidant capacity can be measured using different methods, and in this study, antioxidant levels were assessed using the DPPH and CUPRAC methods. The CUPRAC method is based on the reduction of Cu^{2+} to Cu^{+}, while the DPPH method based on the color change resulting from the neutralization of the DPPH radical (Munteanu & Apetrei, 2021). In this study, it was observed that the antioxidant capacity of Kavacık grapes dipped and micro-perforated by DPPH method varied between 60.58 and 77.44 µmol TE/g dw (Table 2). When evaluating the antioxidant capacity of Kavacık grapes measured by the DPPH method, it was found that pretreatments applied during drying at low temperature (60°C) did not significantly affect the antioxidant capacity ($P > 0.05$). After drying at 70°C, the antioxidant capacities of DG samples differed from those of MG samples ($P < 0.05$), with MG samples showing similar antioxidant capacity values ($P > 0.05$). At 80°C, antioxidant capacities of DG and MG1.0 samples were similar but differed significantly from those of MG0.5 and MG1.5 samples ($P < 0.05$). Overall, the data obtained from the DPPH method indicate that drying temperature significantly affected the antioxidant capacity of DG samples, but had no significant effect on MG samples. Furthermore, it was observed that the antioxidant capacity of MG samples (except at high temperatures) was generally higher than that of DG samples. Antioxidant capacity values of Kavacık grapes measured by the Cuprac method ranged between 124.24 and 178.28 µmol TE/g dw (Table 2). When considering the antioxidant capacity values measured by the CUPRAC method, high temperature appeared to significantly influence both DG and MG samples, creating a notable difference ($P < 0.05$). The results from the two methods differed, likely due to the distinct measurement principles. The CUPRAC method evaluates the antioxidant capacity based on the reduction of the Cu^{2+}–neocuproine (2,9-dimethyl-1,10-phenanthroline) complex to the Cu^{+} form at pH 7, with maximum absorbance at 450 nm. Meanwhile, the DPPH (2,2-diphenyl-1-picrylhydrazyl) method assesses antioxidant activity through the sample's ability to scavenge the stable DPPH• free radical, leading to a decrease in absorbance at 517 nm (Patricia and Syaputri, 2021). In a previous study, the antioxidant content of black grapes dried using hot air was reported as 13.71 µmol TE/g dry matter by the DPPH method and 70.71 µmol TE/g dry matter by the CUPRAC method (Özkan et al., 2022). However, the total antioxidant capacity of Kavacık grapes was significantly higher when measured using these two methods.

Anthocyanins are pigments responsible for the red, purple, blue, and black colors in grapes (Eroğlu, 2012). In this study, it was found that the anthocyanin content of Kavacık grapes was significantly influenced by pretreatment only during the drying process at 70°C ($P < 0.05$). Specifically, MG samples dried at 70°C exhibited higher anthocyanin levels. The effect of drying temperature was more pronounced in DG samples, where the temperature caused a significant difference in total anthocyanin content (TAC) values ($P < 0.05$). In general, the TAC values of MG samples were not significantly affected by changes in drying temperature. In a previous study, the anthocyanin content of black grapes dried using the hot air method was reported to be 46.81 mg mlv-3-glc/100 g

dry matter (Ozkan et al., 2022). In contrast, the anthocyanin content of Kavacık grapes in this study ranged from 61.81 to 70.51 mg mlv-3-glc/100 g dry matter (Table 2), which was higher than the previous findings. This difference can be attributed to variations in grape variety and the pretreatment methods used.

The bioactive contents of the samples dried with a convective dryer are shown in Table 3. It was found that pretreatments caused a significant difference in terms of total phenolic content (TPC) at all drying temperatures ($P < 0.05$). Total phenolic values of MG samples were found to be higher than DG samples for all drying temperatures. While the TPC values of DG samples ranged between 802.70-992.40 mg GAE/100 g dw, the TPC values of MG samples ranged between 953.15-1364.50 mg GAE/100 g dw (Table 3). The results are similar to previous studies and it is thought that the differences are due to the grape variety. For example, it was previously found that the total phenolic content of BRS Vitoria grapes after ethanol and ultrasound pretreatments and convective drying had values between 340.98 and 1794.80 mg GAE/100 g dw (Barbosa da Silva et al., 2023). In another study, the effect of different drying methods on the total phenolic content (TPC) of seedless purple raisins was investigated. The TPC values for room-dried (PRD), shielding film-dried (PFD), and sun-dried (PSD) samples were reported as 536.8 ± 22.3, 436.8 ± 9.2, and 220.5 ± 2.2 mg GAE/100 g, respectively (Qin et al., 2020). These results indicate that the drying method has a significant influence on the preservation of phenolic compounds. In addition, it was observed that the TPC amounts of Kavacık grapes used in these experiments were higher than those used in the static method (Table 2).

In this study, the antioxidant content of Kavacık grapes was evaluated using the DPPH and CUPRAC methods. The results indicated that the antioxidant capacities measured by the DPPH method were significantly influenced by the drying pretreatments, particularly at 60°C and 80°C ($P < 0.05$). It was observed that antioxidant capacity decreased with increasing drying temperature for all samples, and both DG and MG samples showed a significant temperature effect on their antioxidant capacities. However, when the antioxidant capacities measured by the CUPRAC method were considered, pretreatments did not significantly affect the samples dried at the same temperature ($P > 0.05$). Also, it was found that the antioxidant capacities of MG samples were significantly influenced by the drying temperature, while no significant effect was observed in DG samples. The antioxidant values obtained using the DPPH and CUPRAC methods ranged from 57.02 to 161.90 µmol TE/g dry matter and 156.96 to 234.60 µmol TE/g dry matter, respectively (Table 3). The antioxidant values of Kavacık grapes were found to be higher than those reported in studies on black grapes in the literature. For example, the antioxidant content of black grapes dried using the hot air method was 13.71 µmol TE/g dry matter by the DPPH method and 70.71 µmol TE/g dry matter by the CUPRAC method (Ozkan et al., 2022). Similarly, a study by Çoklar and Akbulut (2017) reported the antioxidant capacity of freeze-dried Ekşikara black grapes (Vitis vinifera L.) as 60 µmol TE/g dry matter by the DPPH method. These findings highlight that the antioxidant values of Kavacık grapes are generally higher than those of black grape varieties.

Table 3. Bioactive content of dried grapes (Convective dryer).

Dryer Type		TPC (mg GAE/100 g dw)			
		DG	MG0.5	MG1.0	MG1.5
Convective	60°C	802.70 ± 34.20^{Cb}	1020.00 ± 58.90^{ABb}	953.15 ± 7.80^{Bb}	1128.10 ± 16.90^{Aab}
	70°C	850.20 ± 73.70^{Bab}	1069.30 ± 53.30^{ABb}	1118.60 ± 28.60^{Aa}	1022.70 ± 53.30^{ABb}
	80°C	992.40 ± 35.50^{Ba}	1364.50 ± 20.80^{Aa}	1161.70 ± 25.10^{ABa}	1295.90 ± 130.00^{Aa}
		Antioxidant Capacity (DPPH - µmol TE/g dw)			
	60°C	132.61 ± 5.26^{Ba}	154.14 ± 1.23^{ABa}	152.40 ± 6.83^{ABa}	161.90 ± 7.05^{Aa}
	70°C	112.19 ± 11.53^{Aab}	128.10 ± 0.35^{Aab}	115.20 ± 0.78^{Aab}	116.15 ± 0.56^{Ab}
	80°C	96.99 ± 6.16^{ABb}	122.60 ± 15.70^{Ab}	77.40 ± 22.40^{ABb}	57.02 ± 8.06^{Bc}
		Antioxidant Capacity (CUPRAC -µmol TE/g dw)			
	60°C	156.96 ± 8.06^{Aa}	199.28 ± 12.69^{Aab}	180.28 ± 1.64^{Ab}	205.72 ± 8.06^{Aab}
	70°C	173.63 ± 1.19^{Aa}	178.80 ± 12.09^{Ab}	187.14 ± 0.90^{Ab}	190.52 ± 1.79^{Ab}
	80°C	182.20 ± 19.90^{Aa}	229.67 ± 1.94^{Aa}	232.31 ± 8.06^{Aa}	234.60 ± 17.00^{Aa}
		TAC (mg mlv-3-glc/100 g dw)			
	60°C	12.49 ± 8.20^{Ab}	9.15 ± 1.58^{Ab}	25.55 ± 3.31^{Ab}	18.18 ± 2.68^{Aa}
	70°C	50.76 ± 3.00^{Aa}	14.06 ± 4.10^{Bb}	13.05 ± 2.37^{Bc}	18.63 ± 7.42^{Ba}
	80°C	14.84 ± 8.68^{Ab}	33.02 ± 1.58^{Aa}	33.13 ± 0.47^{Aa}	26.11 ± 2.84^{Aa}

*If means ± standard deviation within a row are shown with different capital letters, there is a statistically significant difference ($P < 0.05$).
**If means ± standard deviation within a column are shown with different lower case letters, there is a statistically significant difference ($P < 0.05$).

Total anthocyanin values of convective dryer-dried, pretreated Kavacık grapes ranged between 12.49 and 50.76 mg mlv-3-glc/100 g dw, while those of micro-perforated Kavacık grapes ranged between 61.69 and 70.51 mg mlv-3-glc/100 g dw (Table 3). In this study, it was found that pretreatments at both low (60°C) and high (80°C) temperatures did not significantly affect the anthocyanin content of Kavacık grapes ($P > 0.05$). A significant difference was observed between DG and MG samples at 70°C, although no significant difference was noted among MG samples with varying needle lengths. Furthermore, the drying temperature influenced the anthocyanin content in all samples except for the MG1.5 samples. In a previous study conducted with Carmenere grapes, the anthocyanin content of freeze-dried and oven-dried grape skins was found to be 14.33 and 12.38 mg mlv-3-glc/100 g dw, respectively (de Torres et al., 2010). In the current study, the anthocyanin content of Kavacık grapes was found to be similar to that of the previous study. The observed differences are likely attributed to variations in pretreatment methods and grape variety.

Conclusion

This study showed that needle micro-perforation is an effective pretreatment method for drying grapes and offers equivalent or superior performance to the traditional immersion method in preserving bioactive compounds. Needle micro-perforation significantly increased the retention of total phenolics, antioxidant capacity and anthocyanins in Kavacık grapes during both static and convective drying processes. Higher bioactive compound values were observed in needle micro-perforated grapes, especially at increasing drying temperatures. The differences were evident in convective drying, indicating the combined effectiveness of airflow and micro-perforation in preserving nutritional quality. Overall, needle micro-perforation is a non-chemical pretreatment alternative that can be used to improve the quality of dried fruits.

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Analysis of Heavy Metals in Soil and Medicinal Plants (*Bryophyllum Pinnatum[BPi]* and *Vernonia Amygdalina [VA]*) using Risk Assessment Indices

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Abstract

The study of heavy metal contamination in soil and plants is crucial in environmental science because it has significant implications for ecosystem health and human well-being. Heavy metals have become environmental pollutants due to human activities such as industrialization, agricultural intensification, and urbanization. The aim of this research is to analyse heavy metals in soil and medicinal plant of Bryophyllum Pinnatum (BPi) and Vernonia Amygdalina (VA) using environmental and health risk indices.

The soil and medicinal plant (leaves, stem, root) for heavy metals (Mn, Fe, Cu, Zn, Cr and Pb) were analysed using Atomic Absorption Spectrophotometer (AAS). The soil and medicinal plant (leaves, stem, root) calculated environmental and health risk assessment. Data were evaluated using descriptive statistics and Pearson correlation. The heavy metal concentrations in soil for BPi and VA ranged from 15.82-217.33 and 366.38-513.60 mg/kg for Mn; 8541.78-9632.78 and 6500.23-16045.03 mg/kg for Fe; 16.30-18.93 and 5.95-23.58 mg/kg for Cu; 161.18-202.35 and 18.88-255.28 mg/kg for Zn; 12.93-18.63 and 6.00-15.58 mg/kg for Cr while Pb is 24.60-30.20 and 0.00-23.65 mg/kg. Heavy metal concentrations in medicinal plants (leaves, stem and root) of BPi and VA ranged from 3.08-72.60 and 8.53-109.13 mg/L for Mn; 36.05-2546.34 and 159.23-382.63 mg/kg for Fe; 5.55-13.68 and 4.13-14.05 mg/kg for Cu; 6.55-104.85 and 9.78-58.78 mg/kg for Zn; 0.0020.75 and 0.00-6.15 mg/kg for Cr while Pb was 0.00-18.08 and 0.00-0.00 mg/kg. Mn, Cu, Zn, Cr and Pb were below the WHO allowable level while Fe especially in the soil was above the WHO permissible limit. The heavy metals was positively correlated in medicinal plants and soil of BPi and VA which are: Mn (1.00 and 1.00); Fe (0.99 and 0.93); Cu (0.93 and 0.77); Zn (0.96 and 0.68); Cr (0.70 and 0.87); Pb (0.95 and 0.67). Ecological risk assessment shows that the soil of the medicinal plants indicates severe pollution. Health risk assessment observes HI < 1, and do not pose non-carcinogenic risk in both plants and soil for adults and children. Also, the two medicinal plants did not pose carcinogenic risk because their Pb and Cr value are 0.00 which is less than $1*10^{-4}$. Non-carcinogenic and Carcinogenic risks assessed on the soil and leaf of plants indicates that the two samples (BPi and VA) can be used for the cure of some illnesses such as cancer and malaria already specified in literature because they have been proven to be below the threshold value.

Keywords: *Heavy metals, Non-carcinogenic risk, Soil, Medicinal plants, Ecological risk*

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Use of Digital Technologies in Agriculture: Comparative Analysis in terms of Production and Marketing

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Abstract

This study first analyses the use of digital technologies in agriculture from two different perspectives. Then, correlation analyses using these data aim to show which countries that focus on which of the two perspectives are ahead in agricultural exports. In the study, publications containing the word 'agriculture' in the title, abstract or keywords section of the Scopus database and the keywords 'digital technology' and 'production' in the all fields section were selected and recorded as publications in which digital technologies in agricultural production were investigated. Then, in the Scopus database, publications containing the word 'agriculture' in the title, abstract or keywords section and the words 'digital technology' and 'marketing' in the all fields section were kept in a separate category and recorded as publications in which digital technologies in marketing of agricultural products were investigated. These two data sets were subjected to correlation analysis with export data obtained from OECD databases, and interactions on the axis of agriculture, digital technologies, production and marketing were revealed. After selecting the OECD member countries with export data from all the data obtained, the number of academic publications of these countries with the specified conditions is given in separate tables. The correlation analysis carried out on OECD member countries revealed a statistically significant and strong positive relationship between the average agricultural export volumes for 2020-2024 and the number of scientific publications containing the terms agriculture, digital technologies and production indexed in the Scopus database. The Pearson correlation coefficient was calculated as $r = 0.813$, and the significance level was $p = 0.004$. When a similar correlation analysis was conducted with publications containing agriculture, digital technologies and marketing terms, the Pearson correlation coefficient was $r = 0.958$ with a significance level of $p < 0.001$. This finding indicates that countries that produce higher levels of academic output in agriculture (publications containing both production and marketing terms) tend to have higher export performance in the agricultural sector. The results suggest that there may be a significant relationship between academic productivity and economic output in international agricultural trade.

Key Words: *Digital Agriculture Technologies, Agricultural Production, Agricultural Marketing, Agricultural Exports, Correlation Analysis*

Introduction

Nowadays, when digital technologies have taken a prominent place in all areas of life, the agricultural sector is also experiencing its share of transformation. This transformation manifests itself both in production processes and marketing processes. On the other hand, businesses that internalise digital technologies in supply chain management and consumer relations have an advantageous position in the competitive market. Digitalisation plays an important role in changing the traditional understanding of agriculture by directly affecting food safety, environmental sustainability and rural development (MacPherson et al., 2022; Lin et al., 2020).

The contributions of digital technologies to the agricultural sector are emphasised at many different points. In their study, Prashanth et al. (2025) emphasise that digital technologies are widely used to increase production efficiency, optimise the use of resources, reduce environmental impacts and improve marketing strategies (Prashanth et al., 2025). In other case studies, it is emphasised that artificial intelligence, Internet of Things (Iot), blockchain, big data analytics and remote sensing technologies contribute to the transformation and development of agriculture (Wolfert et al., 2017; Lin et al., 2020). When all these comprehensive areas are evaluated, the increase in technology-based agricultural practices in developing and developed countries shows that digital agricultural practices have become a global research topic.

This study aims to analyse the effects of digital technologies on agricultural production and marketing processes comparatively. It also reveals the interaction of the use of these technologies with the agricultural export performance of countries. Thus, it tries to show how agricultural digital transformation contributes to production, marketing, foreign trade and global competitiveness.

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In the context of production, Iot-based innovative agricultural applications strengthen decision support processes in areas such as crop management, irrigation systems, crop monitoring and environmental control through data processing (Prashanth et al., 2025). In addition, soil condition and weather conditions can be monitored through sensors and satellite data, making it possible to intervene at the right time (Wolfert et al., 2017). Artificial intelligence and machine learning algorithms facilitate operations in areas such as disease detection, crop recommendation, yield estimation and management of automated agricultural machinery (MacPherson et al., 2022).

In marketing, digital technologies can significantly contribute to delivering agricultural products to the target audience, increasing brand value and making market analyses more accurate (Zhang et al., 2021). Thanks to digital channels such as email marketing, social media, SEO, mobile applications and e-commerce platforms, producers can provide direct access to consumers, thus reducing traditional intermediary structures and improving profit margins (Zhang et al., 2021). In addition, digital marketing has facilitated the opening of agricultural products to global markets.

Considering all these effects, the relationship between academic publication outputs and the agricultural export performance of countries will be evaluated comparatively through the production and marketing perspectives of digital technologies. This evaluation aims to provide guiding information to policymakers, agricultural sector producers, and those who want to market these products by revealing which digitalisation approach is more closely related to agricultural export success.

Materials and Methods

Conceptual Framework

Digital technologies offer support that can provide intensive contributions in the short term in terms of productivity, sustainability and marketing strategies in agriculture to producers and those who want to market agricultural products. At this point, it is important to detail how digital technologies are used in agriculture and to reveal how they are examined in the literature. How digital technologies are used in production and marketing processes in agriculture will be analysed under two main categories. Digital technologies in production and marketing are examined in the literature, respectively.

Digital Technologies in Agriculture Production

Information technologies enable agricultural data storage, transmission and reuse through hardware and software systems. Birt et al. (2012) state that these systems improve data flow in agricultural activities and contribute to decision-making processes. Producers manage resources more effectively by providing accurate and timely access to data; thus, agricultural productivity can increase. In the study by Yechin et al. (2021), business technology contributes to efficiency and coordination in agricultural supply chains.

Communication technologies enable the connection between users and devices through digital networks. Kiambi (2018) states that these technologies facilitate farmers' information sharing in regions such as Africa and increase market access. In production processes, these tools help drive efficient workflows and stronger coordination along the value chain.

Operational technologies secure agricultural systems and support field operations by combining software and hardware. Wei et al. (2024) emphasise that these technologies enable the execution of autonomous processes in large-scale agricultural areas and reduce the need for manual labour. Thus, productivity is increased and cost control is facilitated.

Artificial intelligence technologies enable agricultural processes to be carried out more efficiently from planting to distribution through real-time data and learning algorithms. Akintuyi (2024) states that artificial intelligence increases operational efficiency and contributes to sustainable production choices. Thanks to artificial intelligence technologies, applications that can go beyond autonomy, make their own decisions, and determine their next steps by making inferences from past data add value to agricultural production.

Digital Technologies in Agricultural Marketing

The importance of digital marketing applications in agriculture is addressed from various perspectives. In their analysis, Leng and Tong emphasise the role of digital technologies in supporting the sustainable development of agriculture-related industries (Leng & Tong, 2022). Leng and Tong's research shows that aligning digital marketing with sustainable practices can positively impact producers (Leng & Tong, 2022).

Addressing the regional dimensions of digital technologies in agriculture, Nemchenko et al. emphasise that adopting an innovative approach to agricultural production is essential for the competitive advantage of digitalisation and the change of technological structures (Nemchenko et al., 2020). Beksultanova et al. discuss the comprehensive restructuring required for the agricultural sector to adapt to digital innovations, stating that it increases productivity and enables reaching broader audiences (Beksultanova et al., 2023).

In addition to these studies, some look at the phenomenon from different perspectives and examine the challenges and opportunities sustainable digital marketing can offer in agriculture. Kosior discusses how digital technologies such as big data and Iot can effectively increase productivity and ensure sustainable use of resources in the agri-food sector (Kosior, 2018). Moreover, the role of e-commerce in agricultural wholesale markets should not be ignored. Luo and Wang state that e-commerce platforms can significantly increase farmers' access to broader markets, thus reducing information complexity and minimising agricultural waste (Lou & Wang, 2024).
E-WOM (electronic word-of-mouth marketing) is an important tool in marketing agricultural products, as it is effective in all other sectors. Arslan and Güven's study investigates the effect of online comments on consumers' purchasing behaviour. The role of electronic word-of-mouth communication in shaping consumers' product preferences provides guiding information on the marketing of agricultural products (Arslan & Güven, 2020).
Blockchain technology offers a secure, web-based financial system with encrypted data to ensure the traceability and security of agricultural products. Chiaraluce et al. (2024) state that blockchain technology increases security in agricultural supply chains and prevents fraud (Chiaraluce et al., 2024). This technology is an important tool for providing reliability and transparency in marketing agricultural products.

Method

This study was created with a quantitative research design to comparatively examine the use of digital technologies in production and marketing processes in agriculture. The data in this study were obtained from Bursa Uludağ University, Scopus database and OECD databases between April 5 and April 10, 2025. Within the scope of the research, publications containing the term "agriculture" in the title, abstract or keywords section and the keywords "digital technology" and "production" in the all fields section were identified in the Scopus database. Similarly, to identify the literature on the use of digital technologies in the marketing of agricultural products, publications containing the term "agriculture" and the keywords "digital technology" and "marketing" were searched.
The two data sets obtained were analysed on a country basis to examine the level of adoption of digital technologies in production and marketing processes in agriculture. These data were matched with OECD agricultural export data and used in a correlation analysis. The correlation analysis was conducted to determine how agricultural production and marketing-oriented use of digital technologies relate to export performance.
In the analyses, Pearson correlation analysis was performed using SPSS 26.0 software to determine the interaction between the research of digital technologies in agricultural production and marketing and countries' export performance. The results are visualised and interpreted in order to comparatively assess the effectiveness of digital technologies in the context of agricultural production and marketing.

Results and Discussion

Results

Studies where agriculture and digital technologies intersect with the concept of production

When the publications in the Scopus database containing the term "agriculture" in the title, abstract or keywords section and the keywords "digital technology" and "production" in the all fields section are filtered with the date restriction of 2020-2024, a total of 2370 academic publications appear in the Scopus database. When these publications are analysed bibliometrically, the scientific fields in which the most publications are produced are shown in Table 1 for the Scopus database.
As a result of the query in the Scopus database, the top three scientific fields with the highest number of publications related to the use of digital technologies in agricultural production processes are Agricultural and Biological Sciences (769 publications), Computer Sciences (692 publications) and Environmental Sciences (681 publications). This spatial distribution reveals the interdisciplinary nature of digital agriculture studies. It reveals that technological applications are widely researched and analysed in the agricultural field and different scientific fields.

Table 1: Scientific fields and number of publications obtained in the Production Cluster

	Scientific fields	# of Publications
1	Agricultural and Biological Sciences	769
2	Computer Science	692
3	Environmental Science	681
4	Engineering	551
5	Social Sciences	531
6	Business, Management and Accounting	326
7	Energy	279
8	Economics, Econometrics and Finance	266
9	Earth and Planetary Sciences	219
10	Decision Sciences	153

Table 2: Number of publications by country in the Production Cluster

	Countries	# of Publications
1	China	400
2	Russian Federation	345
3	India	273
4	United States	209
5	Germany	140
6	Italy	137
7	United Kingdom	133
8	Australia	93
9	Canada	79
10	France	77

When the number of academic studies conducted in the context of digital agricultural technologies and production is analysed by countries, China (400 publications) ranks first, followed by Russia (345 publications) and India (273 publications). The academic productivity of these countries in digital agriculture is linked to both their agricultural potential and their interest in technological development. Moreover, this finding reveals that Asian countries make many scientific contributions to digital agriculture.

Table 3: Universities and research institutions producing the most publications in the Production Cluster

	Universities and research organizations	# of Publications
1	Wageningen University	42
2	INRAE	34
3	Russian Academy of Sciences	32
4	University of Guelph	28
5	Northwest University	28
6	Universität Hohenheim	27
7	Russian State Agrarian University - Moscow Timiryazev Agricultural Academy	27
8	University of Johannesburg	21
9	Kuban State Agrarian University	20
10	Université de Montpellier	20

When the universities and research institutions producing the highest number of publications are analysed, Wageningen University ranks first with 42 publications. This institution is followed by INRAE (34 publications) and the Russian Academy of Sciences (32 publications). This situation shows that academic institutions, especially in Europe and Russia, carry out intensive research activities in digital agriculture and are in a leading position.

Studies where agriculture and digital technologies intersect with the concept of marketing

In Scopus databases, when the publications containing the term "agriculture" in the title, abstract or keywords section and the keywords "digital technology" and "marketing" in the all fields section are restricted to 2020-2024, a total of 698 academic publications are obtained in the Scopus database. When these publications are analysed bibliometrically, the scientific fields in which the most publications are produced are shown in Table 4 for the Scopus database.

In the Scopus database, the top three scientific fields with the highest number of publications were Agricultural and Biological Sciences (223 publications), Social Sciences (196 publications) and Computer Sciences (188 publications). This distribution shows that the technical and social aspects of digital marketing are intensively addressed academically. The high ranking of social sciences, in particular, indicates that digital agricultural marketing also focuses on consumer behaviour, communication, and social interaction.

When the publications on digital agricultural marketing are analysed by country, China (115 publications) leads the way, followed by India (87 publications) and the United States (61 publications). This result shows that Asian countries invest in digitalisation not only in production but also in marketing processes. At the same time, the academic productivity of developing countries in this field has been observed at a high level.

Wageningen University (11 publications) ranks first among the institutions with the highest number of publications on digital agricultural marketing, followed by the University of Johannesburg (10 publications) and Northwest University (9 publications). Table 6 shows that universities in Europe and Africa have pioneered digital agricultural marketing research. The fact that universities in South Africa are particularly prominent in this field reveals that regional innovation and digitalisation are also reflected in the academic field.

Table 4: Scientific fields and number of publications obtained in the Marketing Cluster

	Scientific fields	# of Publications
1	Agricultural and Biological Sciences	223
2	Social Sciences	196
3	Computer Science	188
4	Environmental Science	170
5	Business, Management and Accounting	162
6	Engineering	134
7	Economics, Econometrics and Finance	104
8	Energy	83
9	Decision Sciences	53
10	Earth and Planetary Sciences	27

Table 5: Number of publications by country in the Marketing Cluster

	Countries	# of Publications
1	China	115
2	India	87
3	United States	61
4	Russian Federation	45
5	Italy	44
6	United Kingdom	42
7	Germany	41
8	Indonesia	35
9	South Africa	34
10	Australia	29

Table 6: Universities and research institutions producing the most publications in the Marketing Cluster

	Universities and research organisations	#of Publications
1	Wageningen University	11
2	University of Johannesburg	10
3	Northwest University	9
4	Universität Bonn	8
5	South China Agricultural University	8
6	Zentrum für Entwicklungsforschung	7
7	Aristotle University of Thessaloniki	7
8	University of Guelph	7
9	Sichuan Agricultural University	7
10	School of Agriculture	7

Correlation analyses

The correlation analyses conducted in the study were carried out in two different categories, as in the previous sections. The purpose of the correlations in the context of production and marketing is to observe whether there is a correlation between the number of academic research papers and the agricultural export figures of countries.

Table 7 shows the relationship between average agricultural export volumes and the number of academic publications on digital agricultural production in selected OECD countries for 2020-2024. While the United States has the highest number of publications (210 publications), it also has the highest average export volume (28,276.6 tonnes). Countries such as the United Kingdom, Australia and Canada stand out with both high publication productivity and high export figures. This supports a strong positive relationship between academic productivity and export performance. In addition to this finding, another finding that should be noted is that although the number of publications is high in countries such as New Zealand, Colombia and Norway, export volumes are pretty low.

Table 7. Number of Academic Publications on Digital Agricultural Production and Average Agricultural Export Volumes (2020-2024) in Selected OECD Countries

Countries	# of Publications	Agricultural Export data 2020 -2024 Average
United States	210	28276.6
United Kingdom	134	1332.6
Australia	93	16131.7
Canada	79	16906.6
Switzerland	29	89.1
Mexico	19	1053.0
New Zealand	17	0.5
Colombia	17	3.06
Norway	14	1.3
Chile	12	8.6

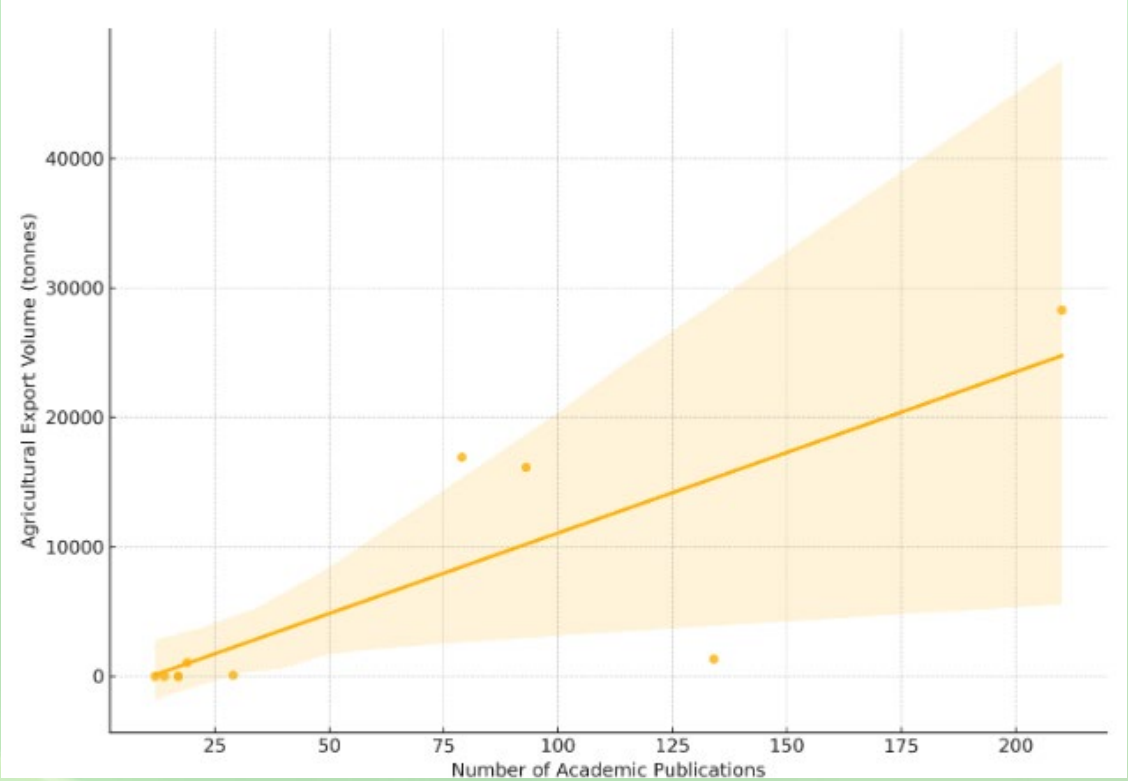


Figure 1. Correlation between Academic Publications on Digital Agricultural Production and Export Volume

The scatter plot in Figure 1 shows the relationship between the average agricultural export volumes in OECD member countries between 2020 and 2024 and the number of academic publications on digital agricultural production. As a result of the correlation analysis, the Pearson correlation coefficient r = 0.813 and the significance level p = 0.004. This strong and statistically significant positive relationship shows that countries that produce more academic publications in digital agricultural production also tend to have higher agricultural export performance.

Table 8 compares the number of academic publications on digital agricultural marketing with the average agricultural export volumes of OECD countries for 2020-2024. The country with the highest number of academic publications is the United States of America (61 publications), which also has the highest export volume (104,526 tonnes). The United States is followed by Canada (19 publications, 53,978 tonnes) and Australia (29 publications, 34,591 tonnes). Turkey is on the list with 11 publications, with an average export volume of 7,644 tonnes. This table provides a numerical result that there may be a strong relationship between the number of academic publications in digital marketing and agricultural export performance.

Table 8. Academic Publications on Digital Agricultural Marketing and Agricultural Export Volumes among OECD Countries (2020-2024)

Countries	# of Publications	Agricultural Export data 2020 -2024 Average
United States	61	104526.38
Canada	19	53978.72
Turkiye	11	7644.79
Australia	29	34591.71
Japan	4	381.57
South Korea	3	613.05
Mexico	5	1223.22
New Zealand	5	117.45
Norway	7	5.01
Switzerland	6	174.92

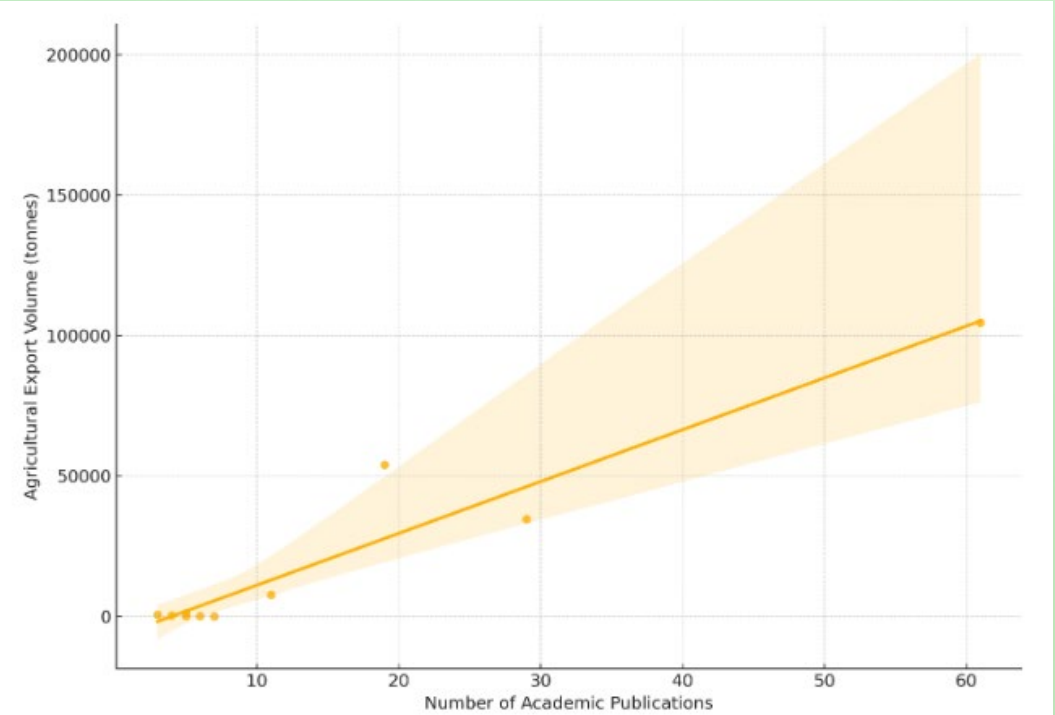


Figure 2. Correlation between Academic Publications on Digital Agricultural Marketing and Export Volume

The correlation analysis conducted on OECD member countries revealed a statistically significant and strong positive relationship between the average agricultural export volumes for 2020-2024 and the number of scientific publications indexed in the Scopus database. The Pearson correlation coefficient was calculated as $r = 0.958$, and the significance level was $p = 0.001$. This result shows a powerful and significant positive statistical relationship between the number of publications related to digital technologies in agricultural marketing and the amount of agricultural exports among OECD members and the 10 highest exporting countries.

Discussion

This study emphasises the power of digital agricultural technologies to improve agricultural production and marketing. The findings obtained from analysing the data draw attention to the positive effects of researching these technologies on the country's export figures by examining how digital technologies are involved in marketing and production areas. The results obtained coincide with the achievements emphasised in the literature. This is in line with previous findings showing that digital technologies can increase production and productivity and are a method of opening up to new markets (Yaman, 2021; Gedik, 2023).

Technologies such as artificial intelligence, remote sensing, and digital sales platforms within the scope of digital agricultural technologies have an important place in changing agricultural production and marketing structures. Digital agricultural technologies reduce production costs in decision-making processes and add value to the product in all processes from the field to the market. While production-oriented innovations contribute to efficient production, they also help sustainable resource utilisation. On the other hand, marketing technologies increase the value of agricultural products by increasing brand visibility and consumer access. The importance of digital technologies for competitive agriculture, emphasised by Yaman et. al (2021) in their study, is also supported in this study.

While this study emphasises the impact of digital technologies in agricultural production through two different phenomena, it has some shortcomings. The first can be summarised as focusing only on countries where agricultural export data are available in OECD databases. Some countries outside these datasets that have a voice in digital agricultural technologies and can actively apply these technologies are not included in the study due to a lack of data. In addition, inconsistencies in the representation of European Union member countries in academic and statistical databases led to their exclusion from the study. This deficiency can be overcome by accessing the export figures of the European Union member countries one by one.

Similar future studies can be repeated using datasets that include export data from alternative sources such as FAO, UN Comtrade, or national statistical agencies. Thus, the mentioned limitations can be overcome. Expanding the scope to include more countries and a more extended time period would allow for a more comprehensive conclusion and evaluation of how digitalisation shapes agricultural trade on a global scale.

This study supports the literature by indicating that digital technologies can be used to improve economic performance in agricultural systems in addition to being facilitative tools. Gedik (2023) emphasises that digital platforms have changed how producers interact with consumers. In their study, Yaman et al. (2021) argue that technological specialisation can significantly affect regional economic outcomes. In this context, it seems possible for researchers and policymakers to maximise regional and global gains by keeping sustainable digital transformation in agriculture more on their agenda.

Acknowledgements

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Effect of Orange Albedo on Nutritional, Functional and Cooking Properties of Semolina Pasta

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Abstract

In this study, the effect of debittered orange albedo on the nutritional, functional and cooking properties of pasta samples was investigated. Orange albedo was substituted into durum wheat semolina at 2.5%, 5% and 10% levels and the moisture, ash, protein, fat, carbohydrate, energy, total phenolic content, antioxidant activity, water uptake and cooking loss of the pasta samples were determined. Albedo substitution increased the fat content ($p>0.05$), ash content ($p<0.05$), carbohydrate content ($p>0.05$) and energy value ($p>0.05$) of pasta samples. Pasta sample without added albedo was found to have the lowest total phenolic content, antioxidant activity, water uptake and cooking loss, and as the albedo substitution rate increased, total phenolic content ($p>0.05$), antioxidant activity ($p<0.05$), water uptake ($p>0.05$) and cooking loss ($p<0.05$) of pasta samples increased. The use of albedo, one of the by-products of the food industry, in pasta production has both increased the functionality of the pasta and recovered a product separated as waste.

Key Words: *Albedo, Debittering process, Functional food, Orange, Pasta*

Introduction

In recent years, the demand for functional foods has increased due to constantly changing consumption habits and increasing population. Pasta is one of the most produced and consumed staple foods in the worldwide (Sissons, 2022). Neutral taste, ease of cooking, low cost and long shelf life are the reasons for its preference (Bustos et al., 2015; Obadi et al., 2021). In pasta production, firstly, durum wheat semolina and water are mixed and kneaded. Then, the obtained dough is shaped by extrusion and lamination. Lastly, the obtained product characterized by its own shape is dried (maximum moisture content 12.5%) and made ready for consumption (Costa et al., 2010). Although durum wheat semolina is rich in carbohydrates (Singh et al., 2023), it is poor in phenolic compounds, vitamins, minerals and dietary fibers (Nilusha et al., 2019). There are studies in the literature where various food industry by-products are included in the formulation in order to increase the functionality of pasta (Carpentieri et al., 2022). Tomato (Padalino et al., 2017), olive (Padalino et al., 2018), grape (Iuga and Mironeasa, 2021), carob (Rodríguez-Solana et al., 2021) and raspberry (De Santis et al., 2022) by-products are some of the materials used to enrich the pasta.

Fruit pulp and peels, which are one of the biggest by-products of the fruit juice industry, are rich in phenolic substances as well as containing high dietary fiber (Sindhu et al., 2019). Citrus fruits are one of the most widely produced and consumed fruits worldwide and contain many phytochemicals that are beneficial for human health (Rafiq et al., 2018). Among citrus fruits, orange is the most preferred type in terms of consumption and processing (Aşık, 2019). Citrus fruit peels consist of two layers called flavedo and albedo. Flavedo is the outer layer, which ranges in color from yellow to orange. Flavedo layer contains carotenoid pigments and lipid cells. Underneath the flavedo is the albedo, a white/cream colored, felt-like layer (Çoksever, 2009). Albedo layer contains loose tissues consisting of large intercellular spaces. It forms a structure consisting mostly of hesperidin and pectin. The majority of pectin, which is found in the citrus fruit peel at a rate of 30-35%, is found in the albedo layer at 73% (Schröder et al., 2004). Albedo layer is preferred because it is an important source of pectin. It has a higher dietary fiber potential and is of better quality than other dietary fiber sources because it contains bioactive compounds with antioxidant properties (Lliso et al., 2007).

The aim of this study is to improve the functional properties of pasta by adding orange peels, one of the by-products of the food industry, to the pasta formulation after subjecting them to various processes. First, the albedo obtained from the orange peel was subjected to the debittering process and then substituted into durum wheat flour at 2.5%, 5% and 10% levels. The nutritional (moisture, ash, protein, fat, carbohydrate, energy), functional (total phenolic content and antioxidant activity) and cooking (water uptake and cooking loss) analyses of the produced pasta were performed.

Materials and Methods

Materials

Durum wheat flour (*Triticum durum* L.) used in the study was supplied by a local producer in Gaziantep, Türkiye and oranges (*Citrus sinensis* L.) were supplied by a local market in Istanbul, Türkiye. All chemicals were used analytical grade.

Albedo production

The methods suggested by Sarıçoban and Unal (2022) and Chaudhary et al. (2024) were used with modifications in the production of albedo. First, the albedo layer was separated from the orange peels. Then, it was subjected to heat treatment at 100 °C for 10 minutes and kept in the same water for 18 hours. At the end of the period, the water was changed and kept in new water for 24 hours and filtered. The albedos, whose bitter taste was removed, were lyophilized (Bruker Co., Germany). The dried albedos were ground and sieved (<500 µm).

Pasta production

100 g durum wheat flour (2.5%, 5% and 10% albedo were substituted) was mixed with 50-70 mL distilled water at 40-45 °C and kneaded. The obtained dough was thinned in a pasta making machine and given the shape of tagliatelle. Pasta cut into 8-10 cm lengths were dried at 50 °C for 5 hours. Pasta without albedo was evaluated as the control (P0) and pasta with 2.5%, 5% and 10% albedo were named P2.5, P5 and P10, respectively.

Determination of nutritional properties

Moisture content of pasta samples was determined by AACC Method No: 44-15.02, ash content by AACC Method No: 08-01.01, protein content by AACC Method No: 46-11.02 and fat content by AACC Method No: 30-25.01 (AACC, 1990). The formula "CHO% = 100 – (Moisture% + Ash% + Protein% + Fat%)" was used to calculate carbohydrate content; the formula "Energy (kcal/100 g) = 4 x (CHO% + Protein%) + 9 x (Fat%)" was used to calculate energy value (Karaağaoğlu et al., 2008).

Determination of functional properties

For the extraction of phenolic compounds, 1 g sample was weighed and 5 mL 80% (v/v) methanol was added. After 15 min in an ultrasonic water bath (Protech, Turkey) and 10 min in an orbital shaker (Stuart SSL1, England), it was centrifuged (Hettich Rotofix 32A, Germany) at 1460 g for 10 min. The supernatant was collected, the sediment was subjected to the same procedures again and the supernatants were combined. The combined supernatants were passed through a 0.45 µm filter and the volume was completed to 10 mL with 80% (v/v) methanol (Czaja et al., 2020). For total phenolic content analysis, 0.1 mL extract was taken into analysis tubes. 2 N 0.2 mL Folin-Ciocalteu reagent and 2 mL distilled water were added. After mixing, it was waited at room temperature for 3 min. At the end of the period, 1 mL 20% (w/v) Na_2CO_3 solution was added. After mixing, it was waited at room temperature for 1 hour. At the end of the period, absorbance was read at 765 nm via the spectrophotometer (PG Instruments Ltd. T60, England). The standard for creating the calibration curve was gallic acid (Wojdyło et al., 2007). For the CUPRAC method (antioxidant activity), 1 mL $1.0x10^{-2}$ M $CuCl_2$ solution, 1 mL 1 M ammonium acetate buffer solution, 1 mL $7.5x10^{-3}$ M Neocuproin solution were taken into the analysis tubes. Then, x mL extract and (1.1-x) mL distilled water were added to make the final volume 4.1 mL. After mixing and waiting in the dark for 1 hour, absorbance was read at 450 nm via the spectrophotometer (PG Instruments Ltd. T60, England). The standard for creating the calibration curve was trolox (Apak et al., 2008).

Determination of cooking properties

In order to determine the optimum cooking time, which is the minimum necessary time required for the starch to completely gelatinize, the pasta was pressed between two glass plates every 30 seconds and the process was repeated until the white part in the middle of the pasta disappeared and the elapsed time was recorded as minutes (Oh et al., 1985). In order to determine water uptake, 20 g pasta was cooked in 250 mL distilled water for the optimum cooking time. The weights of the cooked pasta were determined after draining. The ratio between dry and cooked pasta weights was calculated as water uptake (%) (Özkaya, 2005). In order to determine the cooking loss, the cooking water was evaporated until a fixed weight of 135 °C was reached. The residue was detected. Cooking loss (%) was calculated based on the percentage of the dry pasta weight (Özkaya, 2005).

Statistical analysis

Experimental data were subjected to Variance Analysis using Minitab Version 16.0 (Minitab Inc., PA, USA) program in the form of tables prepared in accordance with the experimental design. Tukey Multiple Comparison Test was used to check whether the differences between the group means were significant. Duplicate measurements were made in all analyses.

Results and Discussion

Nutritional properties

The nutritional analysis results of the pasta samples are presented in Table 1. According to the nutritional analysis results, the moisture content of the pasta samples varied between 13.82-16.43%, ash content between 1.00-1.23%, protein content between 14.15-14.68%, fat content between 0.31-1.19%, carbohydrate content between 67.95-69.73% and energy value between 331.84-345.74 kcal/100 g. Although no statistically significant difference was found between the moisture, protein, fat and carbohydrate contents and energy values of the pasta samples ($p>0.05$), pasta sample without added albedo (P0) was found to have the lowest fat and carbohydrate content and energy value. In addition, as the albedo concentration increased, the fat contents and energy values of the pasta samples increased. P0 pasta was found to have the lowest ash content ($p<0.05$) and ash content increased as albedo concentration increased ($p>0.05$).

Table 1. Nutritional properties of pasta samples.

Sample	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Carbohydrate (%)	Energy (kcal/100 g)
P0	16.43±0.06^{a}	1.00±0.07^{b}	14.32±0.26^{a}	0.31±0.05^{a}	67.95±0.23^{a}	331.84±0.31^{a}
P2.5	13.95±2.15^{a}	1.05±0.08^{ab}	14.55±0.12^{a}	0.73±0.22^{a}	69.73±2.14^{a}	343.65±10.03^{a}
P5	14.28±1.61^{a}	1.13±0.01^{ab}	14.68±0.46^{a}	1.09±0.36^{a}	68.82±1.73^{a}	343.83±8.27^{a}
P10	13.82±2.21^{a}	1.23±0.02^{a}	14.15±0.22^{a}	1.19±0.20^{a}	69.61±2.21^{a}	345.74±9.79^{a}

Values were given as means ± standard deviation. In the same column, different superscripts show significant differences between samples ($p<0.05$). Nutritional properties except moisture are based on dry matter. P0, P2.5, P5, P10 represent pasta samples with 0, 2.5, 5, 10% albedo substitution, respectively.

Dietary fiber was produced from by-products obtained from the orange juice industry and the produced dietary fiber was substituted in the pasta formulation at a level of 25-75%. The ash content of the produced pasta varied between 0.68-0.81%, protein content between 10.92-11.67%, fat content between 0.14-0.24% and carbohydrate content between 80.51-83.56% (Crizel et al., 2015). In the studies carried out, it was determined that as the albedo concentration in breads (Demir and Olcay, 2020) and biscuits (Demirel, 2017) increased, the ash content increased while the protein content decreased.

Functional properties

The functional analysis results of the pasta samples are shown in Figure 1. According to the functional analysis results, the total phenolic content (TPC) value of the pasta samples varied between 21.65-26.30 mg GAE/100 g dm and the antioxidant activity (CUPRAC) value of the pasta samples varied between 81.50-147.75 mg TE/100 g dm. Pasta sample without added albedo (P0) was found to have the lowest TPC ($p>0.05$) value and CUPRAC ($p<0.05$) value. Although the TPC value and CUPRAC value of the pasta samples increased as the albedo concentration increased, no statistically significant difference was found between the pasta samples ($p>0.05$).

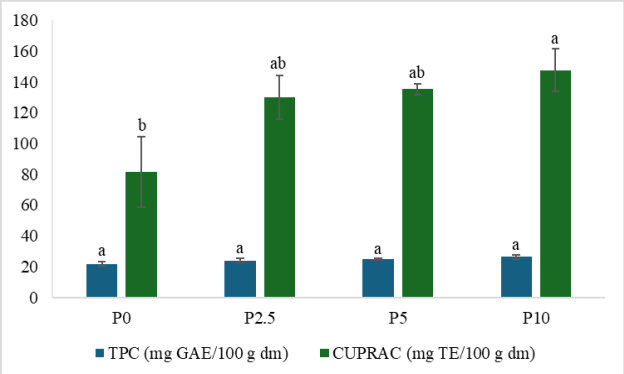


Figure 1. Functional properties of pasta samples. a-b represent the significant differences between samples ($p<0.05$). P0, P2.5, P5, P10 represent pasta samples with 0, 2.5, 5, 10% albedo substitution, respectively.

Orange by-products were substituted into pasta and total polyphenol (1.19-1.68 mg GAE/g) increased as the substitution rate increased (Crizel et al., 2015). Grapefruit albedo was substituted into pasta and DPPH (17.60-38.76%), FRAP (8.57-18.38 µmol AAE/g) and TPC (69.09-167.89 mg GAE/100 g) increased as the substitution rate increased (Chaudhary et al., 2024).

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Cooking properties

The cooking analysis results of the pasta samples are presented in Table 2. According to the cooking analysis results, the water uptake value of the pasta samples varied between 55.20-64.19% and the cooking loss value of the pasta samples varied between 1.82-2.18%. Pasta sample without added albedo (P0) was found to have the lowest water uptake ($p>0.05$) value and cooking loss ($p<0.05$) value. Although the water uptake value and cooking loss value of the pasta samples increased as the albedo concentration increased, no statistically significant difference was found between the pasta samples ($p>0.05$).

Table 2. Cooking properties of pasta samples.

Sample	Water Uptake (%)	Cooking Loss (%)
P0	55.20±1.47^{a}	1.82±0.07^{b}
P2.5	62.15±4.26^{a}	1.93±0.06^{ab}
P5	64.12±1.82^{a}	1.99±0.12^{ab}
P10	64.19±2.60^{a}	2.18±0.02^{a}

Values were given as means ± standard deviation. In the same column, different superscripts show significant differences between samples ($p<0.05$). P0, P2.5, P5, P10 represent pasta samples with 0, 2.5, 5, 10% albedo substitution, respectively.

Orange by-products were substituted for pasta and as the substitution rate increased, water uptake increased from 85.53% to 88.19% and cooking loss increased from 5.57% to 7.98% (Crizel et al., 2015). Grapefruit albedo was substituted for pasta and as the substitution rate increased, swelling index increased from 5.34% to 6.49% and cooking loss increased from 3.47% to 5.02% (Chaudhary et al., 2024).

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Alternative Protein Sources Used in Poultry Nutrition: Insects

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Abstract

In animal nutrition, it is important to provide a balanced diet that is sufficient in terms of protein to ensure the continuity of vital activities. The protein composition of the feed given to the animal should be both economical and sustainable and environmentally friendly. When the protein given to the animal is sufficient, it strengthens the animal's immunity and reduces the risk of contracting diseases, but when it is insufficient, the animals' productivity decreases and if the insufficiency is not met for a long time, it can result in death. In broiler chicken production, where high live weight gain is targeted in a short time, it is important to meet the high protein and energy needs of the animals. In this context, animal and plant protein sources are used to meet the protein needs in poultry nutrition. Today, as a solution to the problems experienced in the supply of these resources as a result of their insufficiency and high cost, sustainable alternative protein and feed raw material searches continue. Insects, potentially requiring less space and water and also being able to be produced quickly on organic wastes, show that they are economically feasible alternative protein sources. In this review, the advantages and disadvantages of using insects in animal nutrition are discussed and studies conducted on poultry nutrition of some insects are mentioned.

Key Words: *Animal nutrition, Insects, Protein source, Poultry, Sustainability*

Introduction

Today, protein sources used in animal feeds are mainly soybean meal, fish meal and processed animal origin proteins. While an increase in resources is expected to meet the protein needs of animals, the decrease in soybean lands and fish stocks worldwide, as well as the last 10 years of information, has caused the price of soybean meal and fish meal to almost double (Jozefiak & Engberg, 2015). The reason for such a pricing increase is the imbalance between supply and demand. One of the main costs in poultry production is feed, and feed costs constitute 60-70% of the production cost. Reducing production costs and providing a cheap protein source that is nutritious for animals is important for sustainability and the environment, and it also provides an important step for people to access animal protein more cheaply (Özek, 2016).

It is important to identify economical and sustainable alternative raw material sources in animal nutrition and to conduct research in this direction. In broiler chicken production, where high live weight gain is targeted in a short time, it is important to meet the high protein and energy needs of the animals. Some protein sources used in broiler chicken rations for high protein requirements are soybean meal, sunflower seed meal, meat meal, meat-bone meal, fish meal. 25-35% of poultry rations contain full-fat soybean and soybean meal (Ergül, 2008; Işık & Kırkpınar, 2017). However, the inadequacy of plant protein sources in meeting the protein needs of broiler chickens has made it necessary to use animal-based protein sources. In our country, in this context, the use of slaughterhouse wastes causes problems due to Salmonella and the inability to fully determine feed values. Of the aforementioned slaughterhouse wastes, meat meal, meat-bone meal and blood meal carry the risk of Salmonella if they are not processed with appropriate methods (Aslantaş, 2004). Insects are thought to be potentially effective in reducing feed costs in broiler feeding. In addition, studies have shown that there is no significant difference in the nutrient composition of insects compared to fish meal and soybean meal, and therefore their use will have a positive effect on production profitability.

Insects

Although they are in the Arhropoda phylum of the animal kingdom, insects (Insecta) constitute the richest class in terms of species diversity (Gillespie et al., 2018). There are almost 1 million insect species named so far, and it has been stated that approximately 2000 of them are suitable for use as human and animal food (Van Huis, 2013). Recently, the use of insects as animal feed in addition to human food has frequently come to the fore and many studies are being carried out in various parts of the world (Erwin, 2004; Sánchez-Muros et al., 2014; Van Zanten et al., 2015; Yüksel & Canhilal, 2018). Insects are natural protein and feed sources for poultry, fish and birds, which are rich sources of protein (Ssepuuya et al., 2017).

Insects may need very different nutrients at different stages of their lives and can feed on a wide variety of waste (restaurant waste, post-harvest plant waste) (Van Huis, 2013). Raising them on biological waste (Khan et al., 2016) has a positive effect on preventing environmental pollution. The rapid growth and high reproductive power of some insect species under suitable conditions are important for the sustainability of production. Insect farming is much more economical when compared to the areas allocated for the cultivation of other protein sources such as forage crops and water requirements, as small areas are used in the cultivation of insects and they generally meet their water requirements from the food they consume. In addition, insect farming is more environmentally friendly when compared to cattle farming, as less greenhouse gas and ammonia are released into nature. In addition, the rate of benefiting from the food consumed by insects is also quite high (Van Huis, 2013). In addition to varying according to insect species and biological period, many insects have protein content ranging from 40-80% and important essential amino acids. Insects are also rich in some minerals (Van Huis, 2013; Sánchez-Muros et al., 2014; Barroso et al., 2014; Henry et al., 2015). The insect species with the highest potential for use as animal feed in the European Union (EFSA, 2015) are shown in Table 1.

Table 1. Insect species with the highest potential for use as animal feed and their information (EFSA, 2015).

Scientific Name	English Name
Musca domestica L. (Diptera: Muscidae)	Common Housefly,
Hermetia illucens L. (Diptera: Stratiomyidae)	Black Soldier Fly
Tenebrio molitor L. (Coleoptera: Tenebrionidae)	Mealworm,
Zophobas atratus F. (Coleoptera: Tenebrionidae)	Giant Mealworm
Alphitobius diaperinus P. (Coleoptera: Tenebrionidae)	Lesser Mealworm
Galleria mellonella L. (Lepidoptera: Pyralidae)	Greater Wax Moth,
Achroia grisella F. (Lepidoptera: Pyralidae)	Lesser Wax Moth
Bombyx mori L. (Lepidoptera: Bombycidae)	Silkworm,
Acheta domesticus L. (Orthoptera: Gryllidae)	House Cricket
Gryllodes sigillatus L. (Orthoptera: Gryllidae)	Banded Cricket,
Locusta migratora migratorioides (Orthoptera: Acrididae)	African Migratory Locust,
Schistocerca Americana D. (Orthoptera: Acrididae)	American Grasshopper,

Advantages and Limitations of Using Insects in Animal Nutrition

The ability to grow insects used in feed on manure and organic waste is important in terms of sustainability as well as preventing environmental pollution. Insects are used not only in their adulthood but also in developmental stages such as larvae and pupae. In addition to their very fast development, their feed utilization is very high. Approximately 2 kg of organic waste and 1 m^2 of area are sufficient to produce 1 kg of insect protein (Van Broekhoven et al., 2015). When considered from an environmental perspective, insects release much less greenhouse gas and ammonia into the atmosphere compared to cattle and pigs for the production of 1 kg of meat (Smith & Pryor, 2014). In addition, it is stated that the use of insects in feed will minimize the damage caused by insects to the product in the field, limit the use of pesticides and contribute to the reduction of environmental pollution (Odabaşı and Yeşilbağ, 2020).

Insects, in addition to their advantages, also bring some risks that need to be considered. These risk factors can be listed as microbial, chemical, toxicological and allergic risks (Odabaşı and Yeşilbağ, 2020). Insects can digest the food they consume thanks to the microbiota in their intestines, and this microbiota can vary depending on the type of insect, the food they feed on and the place where they are grown (El-Tabey, 1951). The microorganisms (bacteria, viruses, etc.) that insects host in their intestines and on their body surfaces can also be found in feeds by participating in the processing stage. These microorganisms can have a pathogenic effect on other insects and the animals that consume them. The most important point to note is that although there is a possibility of pathogenic effects that can reach humans within the food chain, there are few articles reported on this subject. There are studies showing that some microorganisms (Entomopathogens) that cause the death of insects can also be pathogenic for humans (Gerrard et al., 2003; 2004). Insects can contain heavy metals (cadmium and arsenic, etc.), pesticide residues, mycotoxins and plant toxins depending on the plants they feed on. In addition, it is known that some insects can produce their own toxins (Hogan & Razniak, 1991; Devkota & Schmidt, 2000; Zhuang et al., 2009). Although it is known that some insects contain various allergens, no allergic condition has been encountered in the literature as a result of feeding insects to farm animals or pets. (EFSA, 2015).

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The Use of Different İnsects in Poultry

The need for animal protein is increasing day by day and it is predicted that the need for animal protein will increase by 45% between 2010 and 2030 (İpçak & Alçiçek, 2015). However, the scarcity of protein-rich raw materials used in animal nutrition may pose a significant threat to the sector.

Our country faces difficulties in both domestic and foreign markets due to its dependence on imports of some protein-based feed raw materials. Considering that almost 70-80% of the costs in poultry production are feed-based and that primarily rendering products and soybeans are rich in essential amino acids used in feed, changes in the prices of these raw materials can lead producers into financial difficulties. Therefore, it is of critical importance to identify sustainable alternative raw material sources in animal feeding, as well as being economical (Odabaşı & Yeşilbağ, 2021).

The maintenance protein requirement in chickens is low. In other words, a large portion of the protein consumed is used to meet the yield protein requirement. When looking at broiler diets; it is known that the crude protein (CP) rate is 22-25% in the starter period, 21-23% in the grower period, and 19-23% in the finisher period (Ross Broiler Handbook, 2014). Meeting these high levels of crude protein requirements is only possible with animal protein sources. In addition, the protein amount calculated according to the survival and yield period must be balanced with essential amino acids (Odabaşı & Yeşilbağ, 2021).

The protein sources mainly used in broiler nutrition in poultry nutrition are divided into vegetable protein sources (such as soybean meal, sunflower meal, cottonseed meal and canola meal) and animal protein sources (such as fish meal, meat-bone meal, bone meal). Vegetable protein sources are found in lower amounts and have restrictive properties compared to animal protein sources in terms of essential amino acid content, especially lysine and methionine. Animal protein sources can pose a potential risk to animals and humans in terms of contamination with pathogenic bacteria such as Salmonella spp. For this reason, the European Union banned the use of animal protein in food animal husbandry with regulation 999/2001. In Turkey, the use of poultry rendering products in poultry nutrition has been terminated as of January 1, 2017 (Odabaşı & Yeşilbağ, 2021). This review includes studies on the use of different insect species in poultry nutrition.

In order to determine whether maggots can be used as an alternative to fish meal, they used them in broiler feeds at different rates (25-50-75-100%) and it was reported that the most effective maggot usage rate was 25%. As a result, they reached the conclusion that maggots are a cheap feed raw material that can be used instead of fish meal (Awoniyi et al. 2003).

It has been stated that adult field grasshoppers can be used in broiler feeds and that grasshopper meal used up to 15% as an alternative to fish meal did not have any negative effects on live weight gain, feed consumption and feed conversion ratio and can be evaluated especially in disadvantaged regions to fill the protein gap (Wang et al. 2005).

In a study conducted to evaluate Cirina forda larvae as a raw material for poultry feed, 50% and 100% Cirina forda larvae were substituted for fish meal in broiler feeds. As a result of the trial, it was observed that Cirina forda larvae did not significantly change the weight gain and growth rate of the animals. As a result, it was stated that C. forda larvae could be an alternative to traditional fish meal as a protein source (Oyegoke et al. 2006). In another study conducted on Westwood (Crina forda), they conducted a study to determine the effects of using its larvae in laying hen diets as an alternative to fish meal in tropical regions at different rates (0, 25, 50, 75 and 100%) on egg-laying performance and egg quality. As a result of the study, a significant decrease was observed in daily egg production when 100% (Crina forda) larvae were substituted for fish meal in laying hen feeds, and it was concluded that other egg quality parameters, such as egg yolk score, shell thickness and Haugh unit, were not significantly affected. However, it was concluded that Crina forda larvae can be used as up to 75% of fish meal in laying hen diets (Amao et al., 2010).

(Awoniyi, 2007) stated in the study maggots are a good source of protein that can be used in egg production as well as in poultry meat production.

In a study conducted using different rates (5, 10, 15 and 20%) of house fly maggots in broiler diets, the effects of house fly maggots on broiler performance and meat quality were investigated and it was determined that the most effective dose level for broilers was 10-15% of house fly maggots in the diet. It was found that the mentioned dose levels significantly increased carcass yield, breast muscle and thigh muscle ($P<0.05$) (Hwangbo et al., 2009). In a different study, it was reported that Musca domestica (house fly) larvae significantly increased weight gain and feed consumption in broilers when compared to soybean meal containing diets and it was determined that the larvae did not cause any toxicity in the gizzard. It was observed that the carcass and breast muscle ratio increased significantly in the groups receiving 10% house fly larvae compared to the group receiving soybean meal, however, it was concluded that the breast, thigh muscle color and pH parameters were not significantly affected (Pretorius, 2011).

In a study evaluating the meat of chickens raised in pastures with a predominantly locust population in Tibet, it was determined that chickens raised in such pastures had a stronger antioxidant potential and a longer preservation period (Sun et al., 2012).

Jacob (2013) stated that the nutritional components of poultry meat and eggs may differ depending on the type of insect consumed, and it was also determined that the fat content of eggs increased as a result of insect consumption. It has been stated that Hermetia illucens (Soldier Fly), a fly species belonging to the stratiomyidae family of the order of insects (insecta), diptera (Robinson, 2005), can be used for poultry feeding due to its nutrient content (more than 40% protein and more than 30% fat) (Newton et al., 2005). At the same time, it has been determined that thanks to the insect production system combined with chicken coops, it significantly reduces environmental pollution caused by manure (50-60%) and reduces the development of harmful bacteria (Erickson et al., 2004).
Musca domestica (Housefly) is found in the diptera order of insects, in the muscidae family, and it has been stated that it can be evaluated as an excellent protein source, especially in the nutrition of poultry (Işık and Kırkpınar, 2017). When housefly larvae meal was used by replacing fish meal in rations containing 25% fish meal in poultry and when a comparison was made, it was concluded that housefly larvae meal provided a better live weight (Awoniyi et al., 2003).
(Wang et al., 2005) prepared 4 different formulation groups containing different proportions of meadow crickets (0%, 5%, 10% and 15%) in a study conducted with castrated roosters and determined the amino acid properties of meadow crickets and the actual metabolizable energy values accordingly and compared them with fish meal. As a result, the actual digestible amino acid levels of meadow crickets and the actual digestible amino acid levels of fish meal were determined as 92.9% and 91.3%, respectively. As a result of the experiment, no significant difference was observed between the groups when live weight gain, feed consumption and feed utilization rates were taken into consideration in roosters.
In a study conducted by Açıkgöz and Tolon, they stated that silkworm chrysalis flour has the potential to be applied in poultry nutrition (Açıkgöz & Tolon, 2003).

Conclusion and Recommendations

As a result of the predictions of the International Feed Industry Federation (IFIF) and the Food and Agriculture Organization (FAO) that the need for animal protein will increase further by 2050, it is estimated that the cost of animal product production and consumption will be negatively affected. The need for protein sources in the poultry sector, which is among the advanced sectors of our country, will also cause insects, which are among the alternative protein sources, to be considered as a potential protein source in this field. While it has many advantages such as being economical as well as being environmentally friendly, it is one of the alternative protein sources, and it increases concerns due to issues such as the microbial, chemical, toxicological and allergic effects caused by insect production and the lack of standardization in production. It should not be forgotten that more research is needed on the use of different insects in broiler feeds, and it is evaluated that the use of insect-origin protein sources in poultry feed should be implemented within the scope of legislation to be prepared based on scientific data.

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ID: 535

Determination of the Usability of Permeate and Strained Yoghurt Water Separated as Dairy by-product in the Production of a Shalgam-like Product

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Abstract

Fermentation is an effective and economical method used to make a food more durable than it is. Fermented products have an important place in culinary cultures. In Turkish cuisine, which is very comprehensive and rich in terms of fermented products, ayran, vinegar, boza, milk-based and bioactive peptide koumiss, kefir and pickles produced from many vegetables can be consumed as beverages with brine. Shalgam juice is also a fermented beverage and is a part of Turkish culture. Permeate is the liquid part of milk passing through the membrane during ultrafiltration. Permeate, which is a by-product of the ultrafiltration method, contains high levels of protein. Permeate, which is generally not used in factories, is considered as dairy waste and causes environmental pollution. Strained yoghurt is one of the fermented milk products consumed in our country. The yoghurt water released in strained yoghurt production is rich in minerals and lactose. In this study, the usability of strained yoghurt water and permeate water, which are known as waste materials in dairy industry, was investigated. These waste materials are known to be rich in LAB and bioactive substances. Strained yoghurt juice and permeate water were used instead of water in the formulation. Furthermore, the study aimed to determine the effect on the physical and sensory properties of the produced shalgam juice. For this purpose, strained yoghurt juice and permeate water were obtained from the industry for shalgam juice production, and drinking water was used as a control sample. The changes in the processed samples were determined during and after fermentation. Meanwhile, the samples were analysed for pH, acidity, colour and sensory analysis to determine the effects of wastewater on both the progress of fermentation and the final product after fermentation.

Key Words: *Waste treatment, Permeate water, Dairy wastewater, Strained yoghurt juice, Shalgam juice fermentation*

Şalgam Benzeri bir Ürün Üretiminde Sütçülük Yan Ürünü Olarak Ayrılan Permeat ve Süzme Yoğurt Suyunun Kullanılabilirliğinin Belirlenmesi

Özet

Fermantasyon bir gıdayı olduğundan daha dayanıklı hale getirmek için kullanılan etkin ve ekonomik bir yöntemdir. Mutfak kültürlerinde fermente ürünlerin önemli bir yeri vardır. Fermente ürünler bakımından oldukça kapsamlı ve zengin olan Türk mutfağı içerisinde ayran, sirke, boza, süt temelli ve biyoaktif peptit olan kımız, kefir ve birçok sebzeden üretilen turşular salamura sularıyla içecek olarak tüketilebilir. Mevzubahis olan şalgam suyu da fermente bir içecek olup, Türk kültüründe yer almaktadır. Permeat sütün ultrafiltrasyon sırasında membrandan geçen sıvı kısımdır. Ultrafiltrasyon yönteminin bir yan ürünü olan permeat yüksek düzeyde protein barındırır. Fabrikalarda genellikle kullanılmayan permeat sütçülük atığı olarak kabul edilir ve çevre kirliliğine neden olmaktadır. Süzme yoğurt ülkemizde tüketilen fermente süt ürünlerinden biridir. Süzme yoğurt üretiminde açığa çıkan yoğurt suyu mineraller ve laktoz bakımından zengindir. Bu çalışmada, süt ürünleri endüstrisinde atık madde olarak bilinen süzme yoğurt suyu ve permeat suyunun kullanılabilirliği araştırılmıştır. Bu atık maddelerin LAB ve biyoaktif madde açısından zengin olduğu bilinmektedir. Formülasyonda su yerine süzme yoğurt suyu ve permeat suyu kullanılmıştır. Ayrıca, çalışmada, üretilen şalgam suyunun fiziksel ve duyusal özellikleri üzerindeki etkisini belirlemeyi amaçlamıştır. Bu amaçla, şalgam suyu üretimi için sanayiden süzme yoğurt suyu ve permeat suyu temin edilmiş, kontrol örnek olarak ise içme suyu kullanılmıştır. İşlenmiş numunelerdeki değişiklikler fermantasyon süresince ve fermantasyondan sonra belirlenmiştir. Bu sırada örnekler, pH, asitlik, renk analizleri ve duyusal açıdan analiz edilerek, atık suların hem fermantasyonun ilerlemesi hem de fermantasyon sonrası nihai ürün üzerindeki etkileri belirlenmiştir.

Anahtar Kelimeler: *Atık değerlendirme, Permeat suyu, Sütçülük ürünü atık suları, Süzme yoğurt suyu, Şalgam suyu fermantasyonu*

ID: 536

Biostimulants Commonly Preferred in Potato Cultivation in Nevşehir Region and Their Effects on Production

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Abstract

Today, agricultural production faces great challenges in terms of efficiency and sustainability. These challenges require the adoption and implementation of environmentally friendly and innovative solutions in agricultural methods. Biostimulants are materials of natural or biological origin that can be applied to seeds, plants and soil, which promote growth, optimize plant health, and strengthen the cultivated plant against abiotic stress factors when applied in the agricultural production field. Since it is of biological origin and supports environmental sustainability, it is important to make its definition and promotion effective in order to activate and spread it in production. In 1997, Zhang and Schmidt, experts in the Department of Plant and Soil Environmental Sciences at Virginia Tech and State University, defined biostimulants as "small amounts of material that promote plant growth." Some researchers consider biostimulants in the same category as plant nutrition products, based on their similarity in helping plants absorb nutrients and improving product quality. Although the classifications of biostimulants are not completely finalized, important categories have been determined as a result of some studies. Some of these categories have been determined as a result of some studies. Some of these categories are seaweed and plant extracts, amino acids and other nitrogenous compounds, beneficial fungi and bacteria, humic and fulvic acids. In this study biostimulants belonging to different companies were tested and their effects were observed on potato plant, which is widely cultivated in Nevsehir region, in different areas and under different ecological conditions. The aim of this study is to reveal the effects of biological materials on potato production and to raise awareness. As a result of the study, the effects of the biostimulants used on the physiology of the potato plant, its access to nutrients and stress tolerance were compiled.

Key Words: *Biostimulant, Patato, Fulvic acids, Bacteria,Plant extracts*

Nevşehir Yöresinde Patates Yetiştiriciliğinde Yaygın Olarak Tercih Edilen Biyostimülantlar ve Üretimdeki Etkileri

Özet

Günümüzde tarımsal üretimde verimlilik ve sürdürülebilirlik konularında büyük zorluklar ile karşılaşılmaktadır. Bu zorluklar tarımsal metodlarda çevre dostu ve yenilikçi çözümlerin benimsenmesini ve uygulanmasını gerektirmektedir. Biyostimülantlar, tarımsal üretim sahasında uygulandığında büyümeyi teşvik eden, bitki sağlığını optimize eden, abiyotik stres faktörlerine karşı yetiştiriciliği yapılan bitkiyi güçlü kılan, tohuma, bitkiye ve toprağa uygulanabilen doğal veya biyolojik kökenli materyallerdir. Biyolojik kökenli oluşu ve çevresel sürdürülebilirliği desteklemesi nedeniyle üretimde aktifleşmesi ve yaygınlaşması için tanımının ve tanıtımının etkin bir şekilde yapılması önem arz etmektedir.1997 yılında, Virginia Tech ve Eyalet Üniversitesi Bitki ve Toprak Çevre Bilimleri bölümü uzmanları Zhang ve Schmidt, biyostimülanları "bitki büyümesini destekleyen az miktarda malzeme" olarak tanımladılar. Bazı araştırıcılar biyostimülantları bitkilerin besinleri almasına yardımcı olma ve ürün kalitesini artırma konusundaki benzerliklerine dayanarak bitki besleme ürünleri ile aynı kategoride değerlendirmektedir. Biyostimülantların sınıflandırmaları tamamen kesinleşmemekle birlikte önemli kategorileri bazı çalışmalar sonucunda belirlenmiştir. Bu kategorilerden bazıları deniz yosunu ve bitki ekstraktları, amino asit ve diğer azotlu birleşikler, yararlı mantar ve bakteriler, humik ve fulvik asitler olup yapılan bu çalışmada Nevşehir yöresinde yetiştiriciliği yaygın olarak sürdürülen patates bitkisi üzerinde farklı firmalara ait biyostimülantlar farklı alanlarda ve farklı ekolojik koşullarda denenmiş ve etkileri gözlemlenmiştir.Yapılan bu çalışmanın amacı biyolojik kökenli materyallerin patates üretimindeki etkilerini ortaya koymak ve farkındalık oluşturmaktır.Çalışmanın sonucunda kullanılan biyostimülantların patates bitkisinin fizyolojisi, besin elementlerine ulaşımı ve stres toleransına etkileri derlenmiştir.

Anahtar Kelimeler: *Biyostimülant, Patates, Fulvik Asit, Bakteri, Bitki ekstraktları*

ID: 537

A Traditional Fermented Food: Miso

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Abstract

In recent years, the importance of fermented foods such as Miso has become increasingly apparent with the growing interest in healthy nutrition. Miso is a significant fermented product produced and consumed for centuries. In the first century BC, the Miso-like product called "Chiang" in China later spread to Japan and other Eastern countries and was called "Miso". To produce Miso, cooked rice, barley, or soybeans are crushed and fermented with wild mold spores (Koji). Then, the Koji obtained is mixed with salt and water and left for the second fermentation in clay vessels. The duration of fermentation varies depending on the type of Miso, and the color and flavor intensity increase in parallel with the longer fermentation period. While traditional Miso was made in small batches at home, this has been replaced by commercial Miso production in recent years. Miso is particularly rich in essential amino acids. The microorganisms present in Koji and Miso contribute to the product's unique taste, texture, nutritional profile, and positive health effects. Miso is used as a flavor enhancer in both savory and sweet dishes. This review discusses in detail the physical, chemical, bioactive, and sensory properties of Koji and Miso.

Key Words: *Fermantation, Koji, Miso*

Geleneksel Fermente Bir Gıda: Miso

Özet

Son yıllarda sağlıklı beslenmeye olan ilginin artmasıyla birlikte, Miso gibi fermente gıdaların önemi ortaya çıkmaktadır. Miso, çok eski yıllardan bu yana üretilen ve tüketilen önemli bir fermente gıdadır. M.Ö. birinci yüzyılda, Çin'de "Chiang" olarak isimlendirilen Miso benzeri ürün, daha sonra Japonya ve diğer Doğu ülkelerine yayılarak "Miso" olarak adlandırılmıştır. Miso üretimi amacıyla öncelikle pişmiş pirinç, arpa veya soya fasulyesi ezilerek yabani küf sporlarıyla fermente edilmekte (Koji), ardından elde edilen Koji, tuz ve suyla karıştırılarak çömleklerde ikinci fermantasyona bırakılmaktadır. Fermantasyon süresi Miso'nun çeşidine bağlı olarak değişmekte, renk ve lezzet yoğunluğu daha uzun fermantasyon süresine paralel olarak artmaktadır. Geleneksel Miso, evlerde küçük partiler halinde yapılırken, bunun yerini son yıllarda ticari Miso üretimi almıştır. Miso, özellikle esansiyel aminoasitler açısından oldukça zengindir. Koji ve Miso'da yer alan mikroorganizmalar, ürünün benzersiz tadının, dokusunun, besin profilinin ve sağlık üzerine olumlu etkilerinin oluşumunu sağlamaktadır. Miso hem tuzlu hem de tatlı yiyeceklerde lezzet arttırıcı olarak kullanılmaktadır. Bu derlemede, Koji ve Miso'nun fiziksel, kimyasal, biyoaktif ve duyusal özellikleri ile ilgili çalışmalar ayrıntılı olarak tartışılmaktadır.

Anahtar Kelimeler: *Fermantasyon, Koji, Miso*

ID: 428

Utilisation of shalgam juice residue carrot powder in yoghurt production

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Abstract

Yoghurt is a fermented milk product obtained by fermenting milk with lactic acid cultures. It has been the subject of many studies due to its high nutritional value and positive effects on health. Shalgam juice is a traditional drink produced by lactic acid fermentation and is known for its distinctive sour taste and dark red colour. With the increase in shalgam juice production in recent years, a large amount of production surplus is generated in the factories and if it cannot be utilised, it causes economic losses. This study aims to investigate the potential of utilising the black carrot residues released during shalgam juice production in yoghurt production. In this context, shalgam juice residue black carrots were freeze-dried, powdered and added to yoghurt formulations at different ratios (0%, 0.1%, 0.25%, 0.25%, 0.5%, 1.0%, 2.5%) after separating the black carrot from the drinkable shalgam juice. The produced yoghurt samples were analysed for pH, total acidity, dry matter, protein, antioxidant capacity and colour (L*, a*, b*) and the changes in these parameters during storage (1st, 7th, 15th and 21st days) were investigated. The results showed that the addition of fermented carrot powder to shalgam juice residue caused a decrease in pH, L* and b* values of yoghurt, while total acidity, dry matter, antioxidant capacity and a* values increased. In conclusion, fermented black carrot residues resulting from shalgam juice production were found to have functional properties.

Keywords: *Residue, fermented black carrot, Shalgam beverage, Yoghurt*

Şalgam suyu artığı havuç tozunun yoğurt üretiminde değerlendirilmesi

Özet

Yoğurt, sütün laktik asit kültürleriyle mayalanması sonucu elde edilen fermente bir süt ürünüdür. Yüksek besin değeri ve sağlık üzerindeki olumlu etkileri nedeniyle birçok araştırmaya konu olmuştur. Şalgam suyu ise laktik asit fermantasyonu ile üretilen, kendine özgü ekşi tadı ve koyu kırmızı rengiyle bilinen geleneksel bir içecektir. Son yıllarda şalgam suyu üretiminin artmasıyla birlikte fabrikalarda büyük miktarda üretim artığı ortaya çıkmakta ve değerlendirilemediği takdirde ekonomik kayıplara yol açmaktadır. Bu çalışma, şalgam suyu üretimi sırasında açığa çıkan siyah havuç artıklarının değerlendirilerek yoğurt üretiminde kullanım potansiyelini araştırmayı amaçlamaktadır. Bu kapsamda, şalgam suyu artıkları siyah havuç, içilebilir şalgam suyundan ayrıldıktan sonra dondurularak kurutulmuş, toz haline getirilmiş ve farklı oranlarda (%0, %0.1, %0.25, %0.5, %1.0, %2.5) yoğurt formülasyonlarına eklenmiştir. Üretilen yoğurt örneklerinde pH, toplam asitlik, kuru madde, protein, antioksidan kapasite ve renk (L*, a*, b*) analizleri gerçekleştirilmiş, ayrıca depolama sürecinde (1., 7., 15. ve 21. günler) bu parametrelerdeki değişimler incelenmiştir. Elde edilen sonuçlar, şalgam suyu artığı fermente havuç tozu ilavesi yoğurdun pH ve L* ile b* değerlerinde azalmaya neden olurken, toplam asitlik, kurumadde, antioksidan kapasite ve a* değerlerinde artış sağladığını göstermiştir. Sonuç olarak, şalgam suyu üretimi sonucu ortaya çıkan fermente siyah havuç artıklarının fonksiyonel özellikleri artırılmış yoğurt üretiminde değerlendirilebileceği ve böylece gıda endüstrisinde atık yönetimi açısından önemli bir katkı sağlayabileceği belirlenmiştir.

Anahtar Kelimeler: *Atık ürün, Fermente siyah havuç, Şalgam suyu, Yoğurt*

Giriş

Yoğurt kökenine dair kesin bilgiler bulunmamakla birlikte, bazı dini kaynaklar üretiminin M.Ö. 18-17. yüzyıllarda Harran'da başladığını öne sürülen fermente bir gıda ürünüdür (Konar, 1998). TSE 1330, yoğurt standardına göre "Yoğurt, çiğ süt veya pastörize süt standartlarına uygun, tercihen homojenize edilmiş sütlerin *Streptococcus* (*St.*) *thermophilus* ve *Lactobacillus* (*Lb.*) *delbrueckii* subsp. *bulgaricus*'un etkisiyle laktik asit fermantasyonu sonucu elde edilen ve yoğurt kültürlerini canlı olarak ihtiva eden fermente bir süt ürünü" olarak belirtilmektedir (TSE, 2006). Bununla birlikte, yoğurda özgü laktik asit bakterilerinin sütün bileşimindeki karbonhidratı (laktoz) fermente ederek laktik asit üretmesi sonucu oluşan, yüksek besin değerine sahip bir süt ürünüdür. İçeriğindeki canlı mikroorganizmalar yanında, protein ve yağ başta olmak üzere önemli bir besin kaynağı olarak bilinmekte olup

(Çoban, 2017), insan beslenmesinde önemli bir yere sahiptir. Bileşiminde bulunan önemli miktarda su (%83.9-89.5) yanında, laktoz (%3.4-4.5), protein (%3.2-5.6), süt yağı (%1.4-5.6), mineraller (kalsiyum, fosfor, %0.5-1.2) ve vitaminler açısından zengin bir kaynaktır (Gür, 2012; Kürdal ve Demirci, 1980).

Yoğurt üretimi sürecinde, sütün işlenmesinde uygulanan ısıl işlem, mikroorganizmaların zararlı etkilerinin ortadan kaldırılması, yoğurt jelinin ideal şekilde oluşabilmesi için gerekli koşulların sağlanması ve starter kültürlerin sağlıklı bir şekilde aktivasyonunun desteklenmesinde önemli bir rol oynar. Bu işlem, genellikle 80-85°C sıcaklık aralığında 20-30 dakika veya 90-95°C sıcaklıkta yalnızca 5 dakika süreyle uygulanmakta olup, bu işlem sütteki vejetatif mikroorganizmaların öldürülmesini sağlar. Ayrıca, bu işlem, sütün protein yapısında önemli değişikliklere yol açarak serum proteinlerinin denatürasyonunu tetikler. Denatürasyon, proteinlerin üç boyutlu yapılarının bozulması sonucu, sütün kıvamının artmasına ve yoğurt jelinin oluşumuna zemin hazırlar. Bu şekilde, hem mikrobiyolojik güvenlik sağlanırken hem de yoğurt üretimi için uygun fiziksel ve kimyasal ortam oluşturulmuş olur (Tamime ve Robinson, 2000).

Fermantasyon, gıda ve içeceklerin üretiminde kullanılan önemli bir yöntemdir ve bu yöntemle elde edilen ürünler arasında peynir, yoğurt, kefir, kımız, miso, tempe, boza, alkollü içecekler gibi hem evrensel hem de yerel/yöresel nitelikte birçok farklı seçenek bulunur. Bu bağlamda, şalgam suyu da Adana ve çevresine ait, laktik asit fermantasyonu yöntemiyle üretilen, karakteristik asidik tadı ve zengin lezzetiyle öne çıkan bir içecektir. Şalgam suyu üretimi, geleneksel ve direkt yöntemler ile gerçekleştirilen, siyah havuç, tuz, bulgur unu ve su gibi temel bileşenlerin kombinasyonunu içerir. Siyah havuç, şalgam suyunun rengini belirleyen ana bileşen olup, bu bileşenin yoğun mor-kırmızı pigmentleri, şalgamın kendine özgü estetik görünümünü sağlar. Şalgam suyunun üretimi sırasında, mikroorganizma faaliyetleri sonucunda asidik bileşiklerin oluşumu, içeceğin özgün ekşiliğini sağlar ve bu da, şalgam suyunun tüketiciler tarafından beğenilen özel tadım profiline katkı yapar (Canbaş ve Deryaoğlu, 1993; Erten ve ark., 2008; Erten ve Tangüler, 2010).

Gıda üretim süreçlerinde büyük miktarlarda gıda atığı ortaya çıkmakta ve bu atıklar, yanlış yönetildikleri takdirde çevre kirliliğine ve ekosistem üzerinde olumsuz etkilere yol açmaktadır. Bu tür atıkların uygun şekilde işlenmesi, hem ekonomik kayıpların azaltılması hem de çevresel sürdürülebilirliğin sağlanması açısından büyük bir önem taşır. Gıda atıkları, yalnızca çevresel zararın önlenmesi açısından değil, aynı zamanda ekonomik değer yaratma potansiyeli açısından da önemli fırsatlar sunmaktadır. Özellikle meyve ve sebze atıkları, beslenme açısından önemli faydalar sağlayan bir dizi biyolojik aktif bileşen içermektedir. Bu atıklar, diyet lifi, antioksidanlar, pektin, vitaminler gibi besin öğelerinin zengin kaynakları olup, sağlığa faydalı fonksiyonel gıda bileşenlerinin üretimi için kullanılabilir (Carson ve ark., 1994; Jayaprakasha ve ark., 2001).

Son yıllarda, şalgam suyu tüketimindeki belirgin artış, buna paralel olarak üretim süreçlerinde de önemli bir yükselmeye yol açmıştır (Tangüler ve ark., 2024). Bu artış, şalgam suyunun popülaritesinin giderek arttığını ve bunun sonucunda üretim miktarlarında gözle görülür bir yükselişin meydana geldiğini göstermektedir. Bu bağlamda, üretimde kullanılan ana hammaddeler olan siyah havuç (*Daucus carota*), şalgam (*Brassica rapa*) ve setik (bulgur kepeği veya setik) gibi fermente yan ürünlerin artık miktarları da önemli ölçüde artmıştır (Tangüler ve ark., 2021). Bu artan yan ürün miktarı, gıda endüstrisinde sürdürülebilirlik hedefleri doğrultusunda bu atıkların değerlendirilmesi ve potansiyel kullanım alanlarının araştırılması gerekliliğini gündeme getirmiştir. Ancak, şalgam suyu üretimi gibi yerel ve geleneksel gıda işleme süreçlerinden elde edilen atıkların değerlendirilmesine yönelik yapılan bilimsel çalışmalar, henüz yeterli düzeye ulaşmamıştır. Bu durum, özellikle gıda endüstrisinin çevresel etkilerinin azaltılması ve atıkların yeniden kullanımı konusunda yapılacak araştırmaların önemini vurgulamaktadır. Bu yan ürünlerin geri kazanım ve kullanım potansiyelinin değerlendirilmesi, hem ekonomik hem de ekolojik açıdan büyük fırsatlar sunabilir, ancak bu alanda yapılacak daha fazla araştırma ve geliştirme çalışmasına ihtiyaç duyulmaktadır.

Dolayısıyla bu çalışmada, ülkemizde üretimi son yıllarda önemli düzeylerde artan, tüketimi ise ülke sınırlarını aşan şalgam suyu üretiminde bir artık olarak kalan ve genellikle atılan veya hayvan yemi olarak değerlendirilen fermente havuçların değerlendirilmesi yoluna gidilmiştir. Dolayısıyla gerçekleştirilen bu çalışmanın amacı: Şalgam suyu artık ürünü olan havucu değerlendirerek bir katma değer oluşturmak, yoğurdun kurumadde oranını arttırmak, antosiyanince zengin kurutulmuş havuç tozu sayesinde yoğurdun fonksiyonel özelliğini arttırmaya çalışmak, tüketiciler için farklı bir lezzet ve aromada yoğurt üretimini denemek ve ayrıca yoğurt üretiminde kullanılacak havuç tozunun en uygun miktarını belirlemeye çalışmaktır. Bu kapsamda öncelikle artık fermente havuçlar dondurarak kurutulmuş ve toz haline getirilmiş ve farklı oranlarda yoğurt üretiminde kullanılmıştır.

Materyal ve Metod

Materyal

Şalgam suyu artığı havuçlar (ŞAHT) şalgam suyundan içilebilir sıvı kısmın ve setiğin uzaklaştırılması sonucu kalan havuçların temizlenmesi ve karıştırılması ile elde edilmiştir. Öte yandan; pastörize ve homojenize edilmiş süt Niğde'den yerel bir firmadan temin edilmiştir. Yoğurt üretiminde CSL Jointec VH800 (İtalya) karışık starter kültür kullanılmıştır. Yoğurt üretiminde kullanılan sütün pH değeri 6,70, yağ miktarı %3.50 ve kurumadde miktarı %11.8 olarak belirlenmiş ve herhangi bir mikroorganizmaya rastlanmamıştır.

Metod

Şalgam suyu artığı tozunun üretimi

Şalgam suyu artığı havuçlar (ŞAHT) Niğde Ömer Halisdemir Üniversitesi Mühendislik Fakültesi Gıda Mühendisliği Bölümünde üretilen şalgam sularından sıvı kısmın (şalgam suyunun) alınmasının ardından setiğin uzaklaştırılması sonucu kalan havuçların karıştırılmasıyla elde edilmiştir. -50°C sıcaklıkta dondurulmasının (DW-86L628 model, VWR Symphony Ultra-Low Temperature Freezer, Kanada) ardından liyofilizatörde (CoolSafe 95-15 Pro Laboratory Freeze Dryer model, ScanVac LaboGene, Ardından, Kopenhag, Danimarka) düşük sıcaklık (-100oC) ve basınçta (0,001 mbar) 13 kurutulmuştur (Şekil 1). Kurutulan şalgam suyu artık havuçları blender (SHB 3100S model, Sinbo, İstanbul, Türkiye) yardımıyla öğütülerek toz haline getirilmiş ve yoğurt üretiminde kullanılıncaya kadar kapalı cam kavanozlarda muhafaza edilmiştir.



Şekil 1. ŞAHT örneklerinin dondurularak kurutulması

Farklı miktarlarda ŞAHT ilave edilmiş yoğurt üretimi

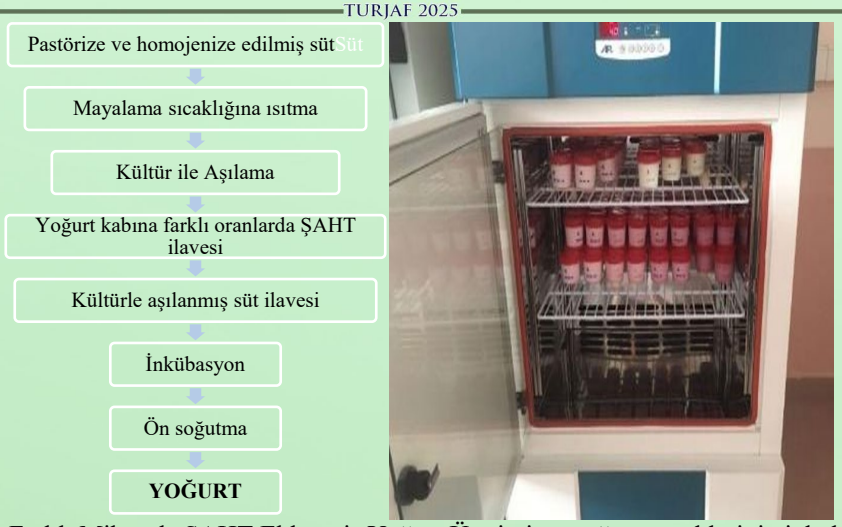
Farklı miktarlarda ŞAHT ilave edilmiş yoğurt üretimi Şekil 2'de yer alan prosese göre gerçekleştirilmiştir. Yoğurt üretimi için pastörize edilmiş homojenize süt çelik bir kap içerisinde 46°C'deki su banyosuna koyulmuş ve süt sıcaklığının 46°C'ye ulaştığında karışık yoğurt starter kültürler üretici firmanın talimatlarına göre %1 oranında ilave edilerek aktifleştirilmiştir. Diğer yandan, 6 ayrı 100 mL'lik kaba sırasıyla %0.0 (kontrol), %0.1 (A), %0.25 (B), %0.5 (C), %1.0 (D) ve %2.5 (E) oranında ŞAHT ilave edilmiştir. Hazırlanan 6 gruptan her biri için 16 adet 100 mL'lik kap hazırlanmıştır. Kültür ilavesi yapılan örnekler, önceden ayarlanmış ve 45°C'ye ısıtılmış inkübatörde (SH-IB149R model, APIN, Ankara, Türkiye) 4 saat inkübasyona bırakılmış ve süre sonunda örneklerin pH değeri kontrol edilmiştir. pH 4,6'ya ulaşınca örnekler analizler için buzdolabına alınmıştır. Depolamanın 1., 7., 15. ve 21. günlerinde 14 kimyasal analizler yapılmıştır. Depolamanın 1.günü protein tayini gerçekleştirilmiştir. Tüm analizler paralelli olarak yapılmıştır.

Protein tayini

ŞAHT ve yoğurt numunelerinin toplam azot içeriği Kjeldahl metodu kullanılarak (Behr Labor-Technik GmbH, Düsseldorf, Almanya) belirlenmiş ve protein miktarları hesaplanmıştır (Kurt ve ark., 1993).

Kurumadde tayini

ŞAHT ve yoğurt örneklerinin (%) kurumadde değerleri gravimetrik yöntem kullanılarak tespit edilmiştir. Kurumadde analizi için kullanılacak kaplar 105±2°C'lik etüvde sabit tartıma gelene kadar kurutulmuş ve ardından desikatörde oda sıcaklığına gelene kadar soğutulmuştur. Ardından kapların darası alındıktan sonra ŞAHT örneklerinden 1'er gram veya homojen yoğurt örneklerinden 3'er gram tartılmış ve yoğurtlar 105±1°C'deki etüvde (Termal G11600S model, Termal Laboratuvar Aletleri San. ve Tic. Koll. Şti., İstanbul) kurutulmuştur. Kurutulan örnekler desikatöre alınarak oda sıcaklığına kadar yaklaşık 25-30 dakika soğutulmuş ve son tartımları yapılmış ve örneklerdeki yüzde (%) kuru madde miktarı belirlenmiştir (A.O.A.C., 1990).



Şekil 2. Farklı Miktarda ŞAHT Eklenmiş Yoğurt Üretimi ve yoğurt örneklerinin inkübasyonu

pH ve toplam asitlik tayini

Üretilen yoğurt örneklerinin pH'sının belirlenmesinde pHenomenal 1000L model (VWR International Ltd., Dublin, İrlanda) dijital pH metre kullanılmıştır. Toplam asitlik tayini, alkali titrasyon yöntemiyle belirlenmiştir. Elde edilen veriler laktik asit cinsine çevrilmiş ve g/L olarak ifade edilmiştir (Cemeroğlu, 2007).

Renk analizleri

Homojen hale getirilen yoğurt örneklerinin ve ŞAHT örneğinin [L* (açıklık (100) - koyuluk (0)), a*(kırmızı (+) - yeşil (-)), ve b* (sarı (+) – mavi (-))] değerleri (Uluslararası Aydınlatma Komisyonu tarafından geliştirilen CIELAB sistemi) kolorimetre (Minolta, CR-400 model, Konica Minolta Optics Inc., Tokyo, Japonya) kullanılarak ölçülmüştür. Kolorimetrenin kalibrasyonu standart beyaz plaka yardımıyla yapılmıştır (standart C ışık kaynağı ile Y=87,1, x=0,3157 ve y=0,3234). Kolorimetrenin koruma başlığı (CR-A33a) takılı optik ucu yoğurt ve ŞAHT örneklerinin yüzeyine (boşluk kalmayacak şekilde) temas ettirilerek C ışık kaynağı kullanılarak ölçülmüştür.

Antioksidan kapasite

Yoğurt ve ŞAHT örneklerinin antioksidan kapasiteleri TEAC yöntemi kullanılarak belirlenmiş olup referans madde olarak Troloks kullanılmıştır. Elde edilen sonuçlar Troloks eşdeğeri olarak kaydedilmiştir. Standart eğri için 1000 ppm'lik Trolox çözeltisi sırasıyla 50-5 ppm arası seyreltilmiş, absorbans ölçülüp % inhibisyon hesaplanarak eğri oluşturulmuştur.

SONUÇLAR VE TARTIŞMA

ŞAHT numunesinin kurumadde, protein ve renk değerleri

Yoğurtlara farklı oranlarda ilave edilen ŞAHT örneğinde kurumadde miktarı %94,51 olarak tespit edilmiş olup, protein miktarı kurumadde üzerinden %13,35 olarak belirlenmiştir.

Protein değerleri

Yoğurtların hem duyusal hem yapısal özelliklerini sütte bulunan protein etkilemektedir. Farklı oranlarda şalgam atığı havuç tozu kullanılarak üretilen yoğurt örneklerinin 0. gününde tespit edilen protein miktarı Tablo 1'de belirtilmiştir.

Tablo 1. Farklı oranlarda ŞAHT ilave edilerek üretilen yoğurt örneklerinin protein değerleri (%)

Yoğurt Örnekleri	Protein Değerleri
K	2,915±0,16
A	2,985±0,19
B	2,990±0,57
C	2,850±0,21
D	2,855±0,01
E	3,195±1,10

K: Kontrol Örneği, A: %0,1 oranında şalgam artığı havuç tozu içeren yoğurt, B: %0,25 oranında şalgam artığı havuç tozu içeren yoğurt, C: %0,5 oranında şalgam artığı tozu içeren yoğurt, D: %1 oranında şalgam artığı havuç tozu içeren yoğurt, E: %2,5 oranında şalgam artığı havuç tozu içeren yoğurt.

Yoğurt örneklerinin protein oranlarının %2,85 ile %3,195 arasında değiştiği belirlenmiştir (Tablo 1). En yüksek protein miktarı %2,50 oranında ŞAHT eklenen numunede ölçülürken, en düşük değer %0,5 ŞAHT içeren numunede tespit edilmiştir. Dolayısıyla genel olarak ŞAHT ilavesinin yoğurtlardaki protein miktarını artırmış olduğu söylenebilir. Çayır (2007) tarafından yapılan araştırmada, yoğurtların protein içeriğinin %3,44 ile %3,74 arasında değiştiği belirlenmiştir. Rahman ve ark. (2001) ise, %5, 10 ve 15 oranında meyve ilave edilen yoğurtlarda, meyve miktarının artışıyla protein oranlarının azaldığını tespit etmiştir.

Hong ve ark. (2020) çalışmalarında, farklı renklerdeki paprika suyu (kırmızı, turuncu ve sarı) ilavesinin yoğurdun biyokimyasal ve antioksidan aktiviteleri üzerindeki etkilerini incelemişlerdir. Çalışmada, *St. thermophilus* ve *Lb. delbrueckii* subsp. *bulgaricus* bakteri kültürleri ile inoküle edilen ve paprika suyu eklenen yoğurt örnekleri hazırlanmış, paprika suyu içermeyen kontrol grubu da oluşturulmuştur. Paprika suyu ilavesinin yoğurdun peptit konsantrasyonunu önemli ölçüde artırdığını belirtmişlerdir. Kontrol yoğurdunun peptit konsantrasyonu 0,11 mg/mL iken, paprika suyu eklenmesiyle bu değer 0,21 mg/mL'ye yükselmiştir. Bu artışın, paprika ilavesi ile birlikte laktik asit bakteri sayısının artırarak, proteinleri önemli miktarda parçalaması ve serbest amino asit miktarını yükseltmesinden kaynaklanmış olabileceği ifade edilmiştir. Ancak, %2,5 oranında turuncu paprika suyu içeren yoğurdun 4°C'de 15 gün boyunca depolanması sırasında peptit konsantrasyonunda önemli bir değişiklik gözlemlenemediği de bildirilmiştir. Hem kontrol hem de paprika içeren yoğurtlarda peptit seviyelerinin depolama süresince sabit kaldığı ve bu durumun depolama sırasında proteinlerin belirgin bir şekilde parçalanmaması ve laktik asit bakteri sayısında büyük bir değişim olmamış olmasına bağlanmıştır.

Depolama süresince yoğurt örneklerinde pH ve toplam asitlik değeri

Üretilen yoğurt örneklerinde pH serbest halde bulunan H+ iyonları konsantrasyonunu ifade etmekte olup, yoğurtlarda raf ömrü, depolama stabiliteleri üzerine etki eden faktörlerdir. Üretilen yoğurt örneklerinin depolamalarının 1., 7., 15. ve 21. günlerinde pH değerleri belirlenmiş ve Tablo 2'de belirtilmiştir.

Tablo 2. Depolama süresince yoğurt örneklerinde pH ve toplam asitlik değişimi

Yoğurt örnekleri	pH				Toplam asitlik			
	Depolama Süresi				Depolama Süresi			
	1. Gün	7.Gün	15.Gün	21.Gün	1. Gün	7.Gün	15.Gün	21.Gün
K	4,28±0,02	4,16±0,005	4,13±0,03	4,13±0,005	0,795±0,014	0,846±0,004	0,849±0,002	0,875±0,005
A	4,19±0,005	4,10±0,005	4,10±0,02	4,12±0,005	0,800±0,009	0,910±0,03	0,824±0,012	0,820±0,029
B	4,20±0,065	4,05±0,01	4,08±0,035	4,11±0,01	0,847±0,003	0,965±0,005	0,874±0,004	0,865±0,055
C	4,09±0,05	4,08±0,005	4,07±0,02	4,12±0,005	0,872±0,0018	0,885±0,005	0,899±0,027	0,865±0,025
D	4,12±0,05	4,10±0,025	4,10±0,005	4,13±0,025	0,868±0,005	0,925±0,005	0,903±0,021	0,890±0,001
E	4,22±0,005	4,14±0,03	4,16±0,04	4,13±0,04	0,825±0,01	0,870±0,001	0,915±0,055	0,900±0,001

K: Kontrol Örneği, A: %0,1 oranında şalgam artığı havuç tozu içeren yoğurt, B: %0,25 oranında şalgam artığı havuç tozu içeren yoğurt, C: %0,5 oranında şalgam artığı tozu içeren yoğurt, D: %1 oranında şalgam artığı havuç tozu içeren yoğurt, E: %2,5 oranında şalgam artığı havuç tozu içeren yoğurt.

Yoğurt örneklerinin inkübasyon sonrası pH değerleri Tablo 2'de gösterildiği gibi 4,09 ile 4,28 arasında değişim göstermiştir. En yüksek pH değeri, ŞAHT ilavesi yapılmayan kontrol grubunda ölçülmüş, diğer örneklerde ise farklı seviyelerde değişimler gözlenmiştir. ŞAHT içeren yoğurt örneklerinde pH değerlerinin kontrol grubuna kıyasla genellikle daha düşük olduğu ve ŞAHT ilavesinin pH'yı düşürdüğü belirlenmiş olmakla birlikte, ilave miktarının artışıyla düzenli bir yükseliş veya azalış eğilimi gözlemlenmemiştir. Kontrol örneğinde depolamanın ilk gününden itibaren pH değerinde azalma meydana gelmiş ve 21. gün itibarıyla pH 4,13 olarak belirlenmiştir. ŞAHT içeren örneklerde ise genellikle 15. güne kadar pH'da bir azalma gözlenmiş, ancak 21. gün itibarıyla artış kaydedilmiştir. 21 günlük depolama işlemi sonunda en yüksek pH değeri (4,13), K, D ve E numunelerinde tespit edilirken, en düşük pH değeri (4,11) B numunesinde belirlenmiştir.

Önceki çalışmalarla karşılaştırıldığında, Karagözlü (1997) tarafından meyveli yoğurtlar üzerinde yapılan araştırmada 28 günlük depolama süresince pH değerlerinin 4,07-4,70 arasında değiştiği belirlenmiştir. Alzamara (2015) tarafından farklı oranlarda kuşburnu marmelatı ilave edilen yoğurtlarda 21 günlük depolama süresince pH değerlerinin 3,88-4,00 arasında değiştiği, Gündoğan (2015) tarafından karamuk konsantresi ve kavut ilavesiyle üretilen yoğurtlarda ise 21 gün boyunca pH değerlerinin 5,32'den 4,22'ye düştüğü bildirilmiştir. Wang ve ark. (2020) yapmış oldukları çalışmada elma posası ilavesi, özellikle %2 ve %3 oranlarında uygulandığında yoğurtların pH değerinde anlamlı bir düşüşe yol açtığını gözlemlemişlerdir. Örneklerde pH değerinin, soğuk depolama süresince azalmış olduğu, buna karşılık titre edilebilir asitlik miktarının arttığı ve 28. gün sonunda en yüksek seviyeye ulaştığı bildirilmiştir. Bu değişiklikler, yoğurtta laktik asit üreten bakterilerin (özellikle *St. thermophilus* ve *Lb. delbrueckii subsp. bulgaricus*) aktivitesine bağlanmaktadır. pH düşüşü ve asitlik artışı en belirgin şekilde ilk 7 gün içinde gözlemlenmiştir. Çakmakçı ve ark. (2012), muz marmelatı ilave edilmiş yoğurt ürünlerinin üretiminde probiyotik bakterilerin (*Lb. acidophilus, Bifidobacterium bifidum* veya bu 2 suşun eşit karışımı) kullanılma olasılığını araştırdıkları çalışmada soğuk depolama süresi boyunca yoğurt örnekleri arasında titre

edilebilir asitlik açısından anlamlı farklar gözlemlenmiştir. Tüm örneklerde asitlik zamanla artarken, pH değerleri azalma eğilimi göstermiştir. Bu durumun, *Lb. delbrueckii subsp. bulgaricus* ve *St. thermophilus*'un neden olduğu postasitifikasyon süreciyle ilişkili olduğu düşünülmüş ve başlangıçta 4,49–4,60 aralığında olan pH değerlerinin, 14 gün sonunda 4,07–4,16 düzeyine gerilediği tespit edilmiştir.

Cho ve ark. (2020) şekerli omija meyvesi ilavesinin yoğurdun kalitesini ve antioksidan aktivitesini iyileştirip iyileştirmediğini belirlemek için yaptıkları çalışmada başlangıçta tüm grupların (şekerli omija ekstraktı eklenmiş, sadece çiğ omija ekstraktı eklenmiş ve herhangi bir ekleme yapılmamış yoğurt örnekleri) pH değerlerinin benzer aralıklarda olduğunu (4,55-4,57), ancak depolama süresi boyunca tüm gruplarda pH değerlerinin düştüğünü bildirmişlerdir (14. günde 4,22-4,38). 7. güne kadar gruplar arasında pH açısından anlamlı bir fark gözlemlenmezken, 7. günden sonra anlamlı farklılıklar ortaya çıkmış ve bu pH düşüşü, laktik asit bakterilerinin laktozu laktik aside dönüştürmesiyle açıklanmıştır. Başlangıçta titrasyon asitliği değerleri %0,94-1,01 arasındayken, 14 gün sonra %0.99-1.05 arasına yükselmiş ve depolama süresi boyunca bu değerler artmıştır.

Nguyen ve Hwang (2016) tarafından yapılan çalışmada, aronia suyu ilavesinin yoğurdun fermantasyon sürecindeki pH ve titrasyon asitliği üzerine etkileri incelenmiştir. Tüm yoğurt örneklerinde fermantasyon süresince pH değerleri düşerken, titrasyon asitliği artış göstermiştir. Aronia suyu içeren gruplarda pH değerleri, içeriğindeki asidik bileşikler nedeniyle kontrol grubuna kıyasla daha düşük bulunmuştur. Özellikle %2 ve %3 aronia suyu eklenen yoğurtlar, 6. saatten itibaren daha yüksek titrasyon asitliği göstermiştir.
Hong ve ark. (2020) yapmış oldukları çalışmada, farklı renklerdeki paprika suyu (kırmızı, turuncu ve sarı) ilavesinin yoğurt üzerinde etkilerini incelemiş ve paprika suyu ilavesi yoğurdun pH değerini düşürmüş ve özellikle %5 sarı paprika suyu içeren yoğurdun pH'ı kontrol grubundan daha düşük bulunmuştur. Ayrıca, paprika suyu, yoğurdun titrasyon asitliği değerini artırmıştır. Depolama süresinin sonunda, her iki grup da pH değerinde düşüş göstermiş, ancak paprika içeren yoğurtlar, kontrol yoğurduna göre daha düşük pH değerine sahip olmuştur. Titrasyon asitliği değerleri ise her iki grupta artmıştır.
Bu çalışmada elde edilen sonuçlar, Karagözlü (1997), Çakmakçı ve ark. (2012), Nguyen ve Hwang (2016), Hong ve ark. (2020) ve Wang ve ark. (2020) tarafından bildirilen bulgularla benzerlik gösterirken, Alzamara (2015) tarafından elde edilen pH değerlerinden daha yüksek bulunmuştur.
Yoğurt üretiminde, süte eklenen laktik asit bakterileri, laktozun fermente edilmesiyle laktik asit üretir. Bu fermantasyon süreci, bakterilerin laktaz enzimi aracılığıyla laktozu glikoz ve galaktoza dönüştürmesiyle başlar ve sonrasında bu şekerler, bakteriler tarafından laktik asit olarak metabolize edilir. Üretilen laktik asit, yoğurdun pH değerini düşürerek ortamın asidik özellik kazanmasına yol açar. pH değeri 4,6'nın altına düştüğünde, süt proteinleri (özellikle kazein) çökelmeye başlar ve bu süreç, yoğurdun karakteristik jelleşmesini sağlar. Toplam asitlik miktarı, kullanılan starter kültürlerin mikroorganizma türlerine, sütün kimyasal bileşimine (özellikle kurumadde ve protein içeriği) ve üretim sürecindeki depolama koşullarına bağlı olarak değişkenlik gösterebilir. Ayrıca, fermente edilen süt ürünlerinin pH ve asidik seviyeleri, yoğurdun fermente edilme süresi, sıcaklık ve saklama koşullarıyla da doğrudan ilişkilidir. Gerçekleştirilen çalışma kapsamında ŞAHT ilavesiyle üretilen yoğurt örneklerinin toplam asitlik değerlerindeki değişimler, depolamanın 1., 7., 15. ve 21. günlerinde ölçülerek Tablo 2'de sunulmuştur.
Araştırmada farklı miktarlarda ŞAHT ikamesi ile üretilen yoğurtların asitlik değerleri 0,795 ile 0,965 arasında değişmiş olup, en düşük değer kontrol grubunda ölçülmüştür. ŞAHT ilavesi, yoğurt örneklerinde asitliği artırmış ancak bu artış %0,5 oranında ŞAHT içeren C örneğine kadar devam etmiştir. Daha yüksek ŞAHT seviyelerinde ise toplam asitlikte azalma gözlenmiştir. Kontrol numunesinde depolama süresince asitlik artmaya devam etmiş ve 21. gün sonunda %0,875 olarak belirlenmiştir. A, B ve D örneklerinde asitlik artışı 7. güne kadar devam ederken, C ve E örneklerinde bu durum 15. güne kadar sürmüştür. Ancak, kontrol grubu dışındaki tüm numunelerde 21. güne kadar az da olsa bir düşüş gözlenmiştir.
Literatürde gerçekleştirilmiş olan çalışmalara bakıldığında, Karagözlü (1997) tarafından yapılan çalışmada, meyveli yoğurtların 28 günlük depolama sürecinde titrasyon asitliği değerlerinin %0,85 ile 1,38 arasında değiştiği ve asitlik seviyesinin zamanla arttığı tespit edilmiştir. Santo ve ark. (2012), çarkıfelek meyvesi lifi içeren probiyotik yoğurtlarda 14 gün boyunca depolama sürecinin titrasyon asitliğini artırdığını raporlamıştır. Uzuner (2012), pirinç sütüyle üretilen probiyotik yoğurtlarda 21 günlük depolama sonunda titrasyon asitliği değerlerinin %0,41 ile %1,14 arasında değiştiğini saptamıştır. Çoban (2017) ise kefir danesi ilavesi yapılan yoğurtlarda depolama süresince genel olarak titrasyon asitliğinin arttığını gözlemlemiştir. Bu çalışmada elde edilen veriler, 15. güne kadar Çoban (2017) tarafından bildirilen sonuçlarla paralellik gösterirken, 15. günden sonra asitlikte hafif bir düşüş gözlenmiş ve bu değişim önemli bir seviyede olmamıştır. Genel olarak, depolama sonunda elde edilen asitlik değerleri, önceki araştırmaların (Karagözlü, 1997; Santo ve ark., 2012; Çakmakçı ve ark., 2012; Nguyen ve Hwang, 2016; Cho ve ark., 2020) bulgularıyla uyumludur.

Depolama süresince yoğurt örneklerinde kurumadde oranı ve antioksidan kapasite değeri

Yoğurt örneklerinin depolama sürecinde yapılan analizlerle elde edilen kurumadde ve antioksidan kapasite değerleri Tablo 3'te verilmiştir. Kurumadde oranları depolamanın 1. gününde %11,76 (kontrol) ile %13,89 arasında değişiklik göstermiş olup, artan ikame maddesi ile artış göstermiştir. Depolama ile beraber genellikle kurumadde değerlerinde azalma gözlenmiştir. 21 günlük depolama sonunda ise yine benzer şekilde en düşük kurumadde miktarı kontrol örneğinde belirlenmişken, en yüksek değer en çok ikame maddesi ilave edilen denemede %13.93 olarak elde edilmiştir.

Tablo 3. Farklı oranlarda ŞAHT İlave edilerek üretilen yoğurtların depolama süresince kurumadde (%) ve antioksidan kapasitelerinin (µmol Trolox Eşdeğeri) değişimi

Yoğurt örnekleri	Kurumadde				Antioksidan kapasite (µmol Trolox Eşdeğeri)			
	Depolama Süresi				Depolama Süresi			
	1. Gün	7.Gün	15.Gün	21.Gün	1. Gün	7.Gün	15.Gün	21.Gün
K	11,76±0,07	11,55±0,03	11,42±0,01	11,50±0,32	35,18±2,7	31,27±3,86	39,18±3,34	27,45±1,80
A	11,81±0,02	11,60±0,11	11,57±0,115	11,61±0,005	40,81±1,67	39,27±4,89	41,81±1,29	27,90±10,16
B	11,87±0,03	11,83±0,05	11,77±0,05	11,62±0,09	57,68±3,28	43,09±14,08	56,99±1,16	37,22±0,19
C	12,21±0,05	11,95±0,03	11,76±0,145	11,95±0,1	85,45±0,64	62,72±7,07	102,95±15,11	69,31±14,46
D	12,88±0,08	12,61±0,2	12,35±0,025	12,55±0,11	136,36±18,64	113,63±3,86	125,681±3,54	89,54±9,0
E	13,89±0,04	14,02±0,005	13,93±0,02	13,39±0,025	217,27±3,21	270,9±2,57	236,81±4,50	190,68±12,53

K: Kontrol Örneği, A: %0,1 oranında şalgam artığı havuç tozu içeren yoğurt, B: %0,25 oranında şalgam artığı havuç tozu içeren yoğurt, C: %0,5 oranında şalgam artığı tozu içeren yoğurt, D: %1 oranında şalgam artığı havuç tozu içeren yoğurt, E: %2,5 oranında şalgam artığı havuç tozu içeren yoğurt.

Öztürk ve Akyüz (1995) meyveli yoğurtlarla ilgili yaptıkları bir çalışmada, sade yoğurdun kurumadde oranlarının meyveli yoğurda göre daha düşük olduğunu ve bu farkın eklenen meyve ve sakkarozdan kaynaklandığını belirtmiştir. Ayar (2002) ise, kızılcık ilaveli yoğurtlarla ilgili çalışmasında, meyve ilaveli yoğurtların kontrol örneğine göre daha yüksek kurumadde oranlarına sahip olduğunu ifade etmiştir. Rahman ve ark. (2001) benzer bir çalışmada, meyve katkılı yoğurtların kontrol yoğurduna göre daha yüksek kurumadde içerdiğini belirtmişlerdir. Bu çalışmada elde edilen sonuçlar, Öztürk ve Akyüz (1995), Ayar (2002) ve Rahman ve ark. (2001) bulgularıyla benzerlik göstermektedir.

ŞAHT örneğine ait antioksidan kapasite değerlerini belirlemek için farklı çözücüler kullanılmıştır. ŞAHT örneğine "Aseton;Su" (%70;30) kullanıldığında antioksidan kapasite 33,63 µM Trolox (v/v) olarak belirlenmişken, "Etanol;Su" (%70;30) (v/v) kullanıldığında 41,35 µM Trolox olarak elde edilmiştir. Buna karşılık, sadece su kullanıldığında antioksidan kapasite 55,43µM Trolox (v/v) olarak bulunmuştur. Dolayısıyla yoğurtlarda antioksidan kapasite değerlerini belirlemek için çözücü olarak sadece su kullanılmıştır.

Yoğurt örneklerinin 21 günlük depolama süresince antioksidan değerlerindeki değişim Tablo 3'te yer almaktadır. ŞAHT ilavesi arttıkça, tüm örneklerde antioksidan kapasite değerlerinde artış gözlemlenmiştir. Depolamanın ilk gününde en düşük değer 35,18 µmol Trolox Eşdeğeri ile kontrol örneğinde, en yüksek değer ise 217,27 µmol Trolox Eşdeğeri ile E örneğinde tespit edilmiştir. Dolayısıyla ilave edilen ŞAHT miktarı arttıkça antioksidan kapasite değerlerinde artış gözlenmiştir. Depolamanın ilk gününden 7. güne kadar antioksidan değerlerinde bir düşüş yaşanırken, 7. günden 15. güne kadar bir artış gözlenmiş, ancak 15. günden sonra değerlerde tekrar bir azalma olmuştur. 21. günün sonunda ise 1. gün değerlerine göre tüm denemelerde azalma gözlenmiş ve en düşük antioksidan değeri 27,45 µmol Trolox Eşdeğeri ile kontrol örneğinde belirlenmişken, en yüksek değer ise 190,68 µmol Trolox Eşdeğeri ile E örneğinde bulunmuştur.

Alzamara (2015) tarafından yapılan bir çalışmada, kuşburnu ve kızılcık marmelatları ilave edilerek üretilen yoğurtların depolama süresince antioksidan aktivite değerlerinin azaldığı ve depolamanın ilk gününde en yüksek değerin 8,43 µmol Trolox Eşdeğeri, son gününde ise 4,35 µmol Trolox Eşdeğeri olduğu belirtilmiştir. Sıçramaz (2025) yapmış olduğu çalışmada, zerdeçal tozunun yoğurda eklenmesinin antioksidan aktiviteyi doza bağımlı bir şekilde artırdığını gözlemlemiş ve zerdeçal ilavesinin yoğurdun antioksidan özelliklerini önemli ölçüde iyileştirdiğini tespit etmiştir. Cho ve ark. (2020) yaptıkları çalışmada, DPPH radikal giderme aktivitesinin depolama süresi boyunca en yüksek çiğ omija ekstraktı içeren yoğurt grubunda gözlemlendiği bildirilmiştir. Şekerli omija ekstraktı ve kontrol grupları arasında 7. güne kadar anlamlı bir fark bulunmazken, 14. günde şekerli omija grubu, kontrol grubuna kıyasla daha yüksek antioksidan aktivite gösterdiği bildirilmiştir. Nguyen ve Hwang (2016) çalışmasında, aronia suyu içeren yoğurtların DPPH ve ABTS radikal giderme aktiviteleri, kontrol grubuna kıyasla önemli ölçüde daha yüksek bulunmuştur. Aronia suyu konsantrasyonu arttıkça antioksidan aktivite değerleri artmıştır. Araştırmacılar tarafından, yüksek antioksidan aktivitenin, aronia suyunun fitokimyasal içeriği ve mikrobiyal metabolik aktivite ile ilişkili olduğu düşünülmektedir.

Amirdivani ve Baba (2015) tarafından yapılan çalışmada, yeşil çayın (*Camellia sinensis*) sütün fermantasyonuna etkisi incelenmiştir. Çalışmada, yeşil çay ekstresi eklenmiş sütün antioksidan aktivite, fenolik bileşikler ve laktik asit bakterilerinin büyümesi üzerindeki değişiklikleri değerlendirilmiştir. Fermantasyon sürecinde, yeşil çay infüzyonu eklenmiş süt, başlangıçta sade süte göre daha yüksek antioksidan aktivite göstermiştir. Fermantasyon sonunda, MGTY (Malezya yeşil çayı yoğurdu) en yüksek DPPH inhibisyonuna sahip olurken, onu Japon yeşil

çayı yoğurdu ve Sade yoğurt izlemiştir. FRAP değerleri açısından da MGTY en yüksek değeri elde etmiştir, ancak fermantasyon süreci, FRAP değerlerinde önemli bir artışa neden olmamıştır. Yeşil çayın mikrobiyal büyümeyi teşvik etmesi ve antioksidan aktiviteye sahip metabolik bileşiklerin oluşumu, antioksidan aktivitedeki artışın olası sebepleri olarak gösterilmektedir. Çalışma ayrıca, soğuk depolamanın yeşil çaylı yoğurtlar üzerindeki bazı fenolik bileşiklerin miktarını etkilediğini ancak bu değişikliklerin yoğurdun antioksidan aktivitesini önemli ölçüde etkilemediğini belirtmiştir. Yeşil çayın sağladığı antioksidan özelliklerin, depolama süresi boyunca nispeten kararlı kaldığı sonucuna varılmıştır. Hong ve ark. (2020) çalışmalarında, farklı renklerdeki paprika suyu (kırmızı, turuncu ve sarı) ilavesinin yoğurdun su ve metanol ekstraktlarının antioksidan aktiviteleri üzerinde önemli bir artış sağladığını belirtmişlerdir. Metanol ekstraktlarının antioksidan aktiviteleri, su ekstraktlarına göre 2 ila 4 kat daha yüksek bulunmuştur. Araştırmacılar tarafından %2,5 oranında turuncu paprika suyu içeren yoğurdun metanol ekstraktının antioksidan aktivitesi en yüksek olarak belirlenmiştir. Ayrıca, depolama süresi boyunca, paprika içeren yoğurtların su ve metanol ekstraktlarının antioksidan aktivitelerinin kontrol yoğurduna göre daha yüksek olduğu bildirilmiştir.

Depolama Süresince Yoğurt Örneklerinde Renk Değerleri

Şalgam artığı havuç tozlarında L* değeri 43,01 olarak belirlenmiş olup, a* ve b* değerleri sırasıyla 32,40 ve 2,02 olarak elde edilmiştir. Bununla birlikte farklı oranlarda ŞAHT eklenerek üretilen yoğurt örneklerinin renk ölçümleri, L* (açıklık-koyuluk) değerleri Tablo 4'te a* ve b* değerleri ise Tablo 5'te sunulmuştur.

Şalgam artığı havuç tozu (ŞAHT) ilavesi arttıkça, yoğurtların koyulaştığı gözlemlenmiştir. Bunun nedeni, şalgam suyu üretiminde kullanılan havuçların antosiyanin pigmentleri açısından zengin olup kırmızı-mor renkte pigmentler içermesidir. Depolamanın 1. gününde L* değeri kontrol örneğinde 88,66 olarak belirlenmişken, ŞAHT ilave edilen denemelerde en düşük değer 58,96 ile E örneğinde ve en yüksek değer 83,46 ile A örneğinde belirlenmiştir. Öte yandan, depolama süresince L* değerlerinde genellikle düzenli bir artış görülmüş, yani renk solmuş ve yoğurtlar daha açık hale gelmiştir. 21 günlük depolama sonunda kontrol örneğinde L* değeri 97,3 ile yine en yüksek değer olarak belirlenmiştir. Bununla birlikte, ŞAHT ilave edilen denemelerde en düşük değer yine E örneğinde (66,5) ve en yüksek değer A örneğinde 92,16 olarak bulunmuştur.

Alzamara (2015) tarafından yapılan bir çalışmada, kuşburnu ve kızılcık marmelatları ilave edilen yoğurtlarda L* değerlerinin depolamanın ilk gününde 85,37 ve 21. gününde ise 83,49 olduğu ve 21 gün boyunca L* değerlerinin azaldığı belirtilmiştir. Bizim denememizde ise elde edilen L* değerleri depolamanın başlangıcında benzer iken, depolama ile kısmen de olsa azalması bakımından çalışmamızdan farklı olarak görülmüştür. Bu farklılığın meyvedeki karoten pigmentlerinden kaynaklanıyor olabileceği düşünülmektedir.

Tablo 4. Depolama süresince yoğurt örneklerinin L* değerlerindeki değişim

Yoğurt Örnekleri	Depolama Süresi			
	1. Gün	7.Gün	15.Gün	21.Gün
K	88,66±0,08	88,47±0,27	88,69±0,14	97,30±0,33
A	83,46±0,095	86,19±2,51	83,94±0,11	92,16±0,21
B	79,67±0,0235	79,63±0,495	80,41±0,285	87,96±0,18
C	74,97±0,24	75,07±0,01	77,04±0,29	82,87±0,225
D	69,23±0,7	69,36±0,075	70,95±1,14	76,68±0,17
E	58,96±0,62	59,38±0,335	60,88±0,57	66,50±0,55

K: Kontrol Örneği, A: %0,1 oranında şalgam artığı havuç tozu içeren yoğurt, B: %0,25 oranında şalgam artığı havuç tozu içeren yoğurt, C: %0,5 oranında şalgam artığı tozu içeren yoğurt, D: %1 oranında şalgam artığı havuç tozu içeren yoğurt, E: %2,5 oranında şalgam artığı havuç tozu içeren yoğurt.

Kontrol örneğinde a* değeri negatif değerde olup, ŞAHT ilave edilen örneklerde pozitif olarak belirlenmiştir. Dolayısıyla kontrol örneği diğer örneklerden daha yeşil bir renk tonuna sahiptir. Depolamanın 1. gününde artan ŞAHT ilavesi ile a* değerinin arttığı belirlenmiş olup, ŞAHT oranı arttıkça yoğurt örneklerinde kırmızılık değerlerinin arttığı gözlemlenmiştir (Tablo 5). Bunun nedeni, siyah havuçta bulunan antosiyanin pigmentleridir. Kontrol örneğinin a* değeri depolamanın başlangıcında -3,25 iken, en düşük miktarda ŞAHT ilave edilen örnekte a* değeri +4,52 ve en yüksek değeri E örneği ile +23,08 olarak belirlenmiştir. 21 gün sonunda, tüm denemelerde (A örneği hariç) a* değerlerinde artış gözlemlenmiştir ve a* değerleri -3,195 ile 24,875 arasında değişmiştir. Alzamara (2015) tarafından yapılan bir çalışmada, kuşburnu ve kızılcık marmelatları ilave edilen yoğurtlarda a* değeri depolamanın 1. gününde 5,35 ve 21. gününde ise 4,09 olarak tespit edilmiştir. Çoban (2017) ise kefir danesi ilavesi yapılan yoğurtlarda kontrol örneğinde a* değerini -4,32 olarak belirlemiştir. Gerçekleştirilen çalışmamızda ise, kontrol örneğinin a* değeri -3,25 olup, Çoban (2017) ile benzer sonuçlar elde edilmiştir.

Tablo 5. Depolama süresince yoğurt örneklerinin a* ve b* değerlerindeki değişim

Yoğurt örnekleri	a*				b*			
	Depolama Süresi				Depolama Süresi			
	1. Gün	7.Gün	15.Gün	21.Gün	1. Gün	7.Gün	15.Gün	21.Gün
K	-3,25±0,09	-3,27±0,015	-3,38±0,095	-3,2±0,125	7,38±0,025	7,17±0,01	7,68±0,005	6,67±0,035
A	4,52±0,05	4,10±0,13	4,2±0,085	4,15±0,435	3,80±0,04	4,35±0,25	4,23±0,13	3,51±0,03
B	9,05±0,24	8,87±0,46	8,81±0,14	9,41±0,025	2,47±0,105	2,95±0,185	2,77±0,3	1,61±0,0805
C	13,40±0,08	12,70±0,06	12,84±0,535	14,34±0,065	1,84±0,07	2,33±0,11	1,93±0,425	1,32±0,355
D	18,03±0,36	17,58±0,34	17,4±0,205	18,73±0,19	1,66±0,755	1,77±0,22	1,38±0,75	1,41±0,6
E	23,08±0,37	22,85±0,635	23,29±0,485	24,88±0,065	0,86±0,855	1,08±0,075	0,33±0,09	1,23±0,27

K: Kontrol Örneği, A: %0,1 oranında şalgam artığı havuç tozu içeren yoğurt, B: %0,25 oranında şalgam artığı havuç tozu içeren yoğurt, C: %0,5 oranında şalgam artığı tozu içeren yoğurt, D: %1 oranında şalgam artığı havuç tozu içeren yoğurt, E: %2,5 oranında şalgam artığı havuç tozu içeren yoğurt.

Denemelerde, yoğurt örneklerine eklenen ŞAHT oranı arttıkça, yoğurtların sarılık değerlerinde azalma gözlemlenmiştir, bu durum Tablo 5'te gösterilmiştir. Kontrol örneğinde b* değeri 7,38 olarak belirlenirken, en düşük ŞAHT ilave edilen A denemesinde 3,80 ve en fazla ŞAHT eklenen E örneğinde bu değer 0,86 olarak tespit edilmiştir. Depolama süresi boyunca b* değerinde düzensiz bir değişiklik gözlemlenmiştir. Bununla birlikte, depolamanın başlangıcına göre, depolamanın 21. Gününde elde edilen b* değerlerinde (E denemesi dışında) azalma gözlenmiştir. Depolama sonunda, en yüksek b* değeri (6,67) kontrol örneğine aitken, en düşük değer ise E örneğinde 1,23 olarak bulunmuştur. Alzamara (2015) tarafından yapılan bir çalışmada, kuşburnu ve kızılcık marmelatları eklenen yoğurtlarda b* değeri 1,03 olarak tespit edilirken, 21. gün sonunda bu değer 2,58'e yükselmiş ve b* değerinin arttığı bildirilmiştir.

Wang ve ark. (2020) yapmış oldukları çalışmada, elma posası ilavesiyle birlikte yoğurtların renk parametrelerinde anlamlı farklılıklar gözlemlendiğini bildirmişlerdir. Açıklık (L*) değeri azalmış, buna karşılık kırmızımsılık (a*) ve sarılılık (b*) değerlerinin artmış olduğu belirlenmiş ve bu durumun elma posası ile zenginleştirilmiş yoğurtların kontrol grubuna kıyasla daha yoğun kırmızımsı ve sarımsı bir renge sahip olduğunu gösterdiğini bildirmişlerdir. Sıçramaz (2025) yapmış olduğu çalışmada, ilave edilen zerdeçal tozu konsantrasyonu arttıkça yoğurdun L* ve a* değerlerinin azaldığını, b* değerinin ise önemli ölçüde arttığını tespit etmiştir. Bu renk değişikliklerinin tamamen artan zerdeçal tozu konsantrasyonundan kaynaklandığı belirtilmiştir. Cho ve ark. (2020) çalışmasında, yoğurtlara çiğ ve şekerli omija ekstraktı ilavesinin renk parametrelerini etkilediği bildirilmiştir. Açıklık (L*) değeri en yüksekten en düşüğe doğru kontrol, şekerli omija ve çiğ omija ekstraktı şeklinde sıralanmış; çiğ omija ekstraktı daha koyu renk oluşumuna neden olduğu bildrilmiştir. Depolama süresi boyunca ise tüm gruplarda L*, a* (kırmızılık) ve b* (sarılık) değerlerinde azalma gözlemlenmiştir. En yüksek a* değeri çiğ omija ekstraktı grubunda bulunmuş, bu da antosiyanin içeriğiyle ilişkilendirilmiştir. Nguyen ve Hwang (2016) çalışmasında, aronia suyu ilavesinin yoğurtların daha kırmızı, daha koyu ve daha az sarı renge sahip olduğunu bildirmiştir. Fermentasyon süresince tüm gruplarda açıklık (L*) değerlerinde artış gözlemlenirken, kırmızılık (a*) ve sarılık (b*) değerlerinde farklı eğilimler gözlemlenmiştir. Hong ve ark. (2020) çalışmalarında, paprika suyu ilavesinin yoğurdun rengini belirgin şekilde değiştirdiğini belirtmişlerdir. Kırmızı paprika ilavesinin kırmızılık (a*) değerini artırdığını, turuncu paprika ilavesinin ise parlaklık (L*) değerini azaltıp, kırmızılık ve sarılığı (b*) artırmış olduğunu belirlemiştir. Sarı paprika ilavesinin ise parlaklık değerini korurken, sarılığı artırdığı ifade edilmiştir.

Sonuç

Bu çalışmada, şalgam suyu üretiminde ortaya çıkan önemli miktardaki siyah havuç artığının kurutularak toz haline getirilmesi (ŞAHT) ve bu tozun farklı oranlarda yoğurt üretimine (%0, %0.1, %0.25, %0.5, %1.0, %2.5) dahil edilmesinin yoğurdun bazı özellikleri üzerindeki etkileri incelenmiştir. Gerçekleştirdiğimiz bu çalışmadan elde edilen sonuçlar, ŞAHT'nin yoğurtların protein içeriği, pH, toplam asitlik, kurumadde oranı, antioksidan kapasite ve renk özellikleri üzerinde önemli değişikliklere yol açtığını göstermektedir. Elde edilen sonuçlar, *b* değerinde düşüşe, buna karşılık toplam asitlik, kurumadde, antioksidan kapasite ve a* değerlerinde ise artışa neden olduğunu göstermiştir. Fonksiyonel özellikler açısından bakıldığında, ŞAHT ilavesiyle yoğurtların antioksidan kapasitesinde önemli bir artış sağlanmıştır. Sonuç olarak, bu çalışma şalgam suyu endüstrisinden kaynaklanan siyah havuç atığının yoğurt üretiminde kullanımı açısından büyük bir potansiyele sahip olduğunu, yoğurt üretiminde başarılı bir şekilde kullanılabileceğini ve bu sayede hem atık değerlendirilerek ekonomik bir kazanç sağlanabileceğini hem de yoğurdun fonksiyonel özelliklerinin zenginleştirilebileceğini göstermektedir. Özellikle düşük konsantrasyonlarda ŞAHT ilavesinin yoğurdun kalitesini olumlu yönde etkileyebileceği ve tüketiciler için farklı özelliklere sahip yeni yoğurt çeşitlerinin geliştirilebileceği düşünülmektedir. Elde edilen veriler, çevresel sürdürülebilirlik açısından da önemli bir yer tutmaktadır, çünkü şalgam suyu üretiminden çıkan atıkların değerlendirilmesi, gıda atıklarının yönetimi konusunda yeni bir yaklaşım sunmaktadır. Gelecek çalışmalarda, farklı ön işlemlerin ve daha düşük ŞAHT konsantrasyonlarının etkileri detaylı olarak incelenebilir.

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Professional Practice Knowledge in Interior Architecture Education, Exploration, Quantity Surveying and Approximate Cost

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Abstract

Interior architecture education is a branch of science that covers topics such as design knowledge and skills, material knowledge, construction site application information and cost calculations as well as theoretical knowledge. In addition to the basic design knowledge of the students in the education process, there are also courses on professional practice. The aim of these courses is to address the procedures to be done before and during the application phase of the project in the construction site environment. In the interior design project, the quantity quantities of the materials decided in the design process according to the units, wastage calculations, position numbers, approximate cost (discovery) should be managed by the interior architect before proceeding to the application phase. In this context, the study examines the course content applied within the scope of Building Quantity Surveying and Exploration, which is a compulsory course in the 7th semester curriculum of Selçuk University Faculty of Architecture and Design, Department of Interior Architecture. Within the scope of the course, the interior design project stages of the physically determined space, survey, quantity survey, exploration and approximate cost calculations are discussed. Within the scope of the study, 4th year interior architecture students were asked to redesign the classroom number 411, where the Building Quantity Surveying and Exploration course was carried out, with the same function. Within the scope of the project, the design process, survey, quantity surveying, exploration and organization order of the works to be applied and approximate cost calculations were requested. It is expected that this study will contribute to the literature and provide an example of how approximate bill of quantities and cost calculations can be made in the field of interior architecture.

Key Words: *Interior Architecture, Professional Practice, Quantity Surveying, Estimated Cost*

İç Mimarlık Eğitiminde Mesleki Uygulama Bilgisi, Keşif, Metraj ve Yaklaşık Maliyet

Özet

İç mimarlık eğitimi, teorik bilgilerin yanı sıra tasarım bilgi ve becerisi, malzeme bilgisi, şantiye uygulama bilgileri ve maaliyet hesapları gibi konuları kapsayan bilim dalıdır. Öğrencilerin eğitim sürecinde temel tasarım bilgileri yanı sıra, mesleki uygulama içerikli dersleri de yer almaktadır. Bu derslerin amacı, öğrencileri şantiye ortamında projenin uygulama safhasın ve öncesinde yapılması gereken işlemleri ele almaktır. İç mimari projede tasarım sürecinde karar verilen malzemelerin birimlerine göre metraj miktarlarının çıkartılması, fire hesapları, pozisyon numaraları, yaklaşık maaliyeti (keşif), uygulama aşamasına geçmeden önce, iç mimar tarafından yönetilmelidir. Bu kapsamda çalışma Selçuk Üniversitesi Mimarlık ve Tasarım Fakültesi İç Mimarlık bölümü 7. Dönem müfredatında zorunlu ders olarak yer alan Yapı Metraj ve Keşif kapsamında uygulanan ders içeriğini incelemektedir. Ders kapsamında fiziki olarak belirlenen mekânın iç mimari proje aşamaları, rölöve, metraj, keşif ve yaklaşık maaliyet hesaplamaları ele alınmıştır. Çalışma kapsamına İç mimarlık 4. Sınıf öğrencilerinin, Yapı metraj ve Keşif dersinin yürütüldüğü 411 numaralı dersliğin aynı fonksiyon ile yeniden tasarlanması istenmiştir. Proje kapsamına tasarım süreci, rölöve, metraj, keşif ve uygulanacak işlerin organizasyon sıralaması ve yaklaşık maaliyet hesapları istenmiştir. Bu çalışmanın iç mimarlık alanında yaklaşık metraj cetveli ve maliyet hesaplamalarının nasıl yapılabileceğine yönelik bir örnek oluşturması ve literatüre katkı sağlaması beklenmektedir.

Anahtar Kelimeler: *İç Mimarlık, Mesleki Uygulama, Keşif, Metraj, Yaklaşık Maliyet*

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Gluten-free Noodles from Cassava-Bambara groundnut Composite Flour: Physicochemical Properties and Consumer Acceptability

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Abstract

The aim of this study was to develop gluten-free noodles with enhanced nutritional quality using cassava and Bambara groundnut flours as alternative ingredients. A combined mixture-process design was applied to investigate the effects of two mixture components (cassava and Bambara groundnut flours) and two process factors (whole egg and xanthan gum) on the quality attributes of noodles. The responses (protein content, ash content, L*-values, Hue, chroma, browning index, weight gain, and cooking loss) were modelled by mixture-process equations. The results indicated that the protein, ash, and weight gain of the noodles increased with an increase of both cassava and Bambara groundnut flours. The noodles were optimised based on the desirability function and three optimal formulations were selected for sensory evaluation. The formulation with the highest desirability index (0.82) consisted of 70.4 % cassava flour, 29.57 % Bambara groundnut flour, 40 % whole egg, and 0.49 % xanthan gum. However, the sensory panel preferred the formulation without Bambara groundnut flour (100% cassava flour, 36.92% whole egg, and 0.23% xanthan gum), although the addition of Bambara groundnut flour enhanced protein, ash, fat and fibre contents, weight gain, phytochemical composition, hardness, chewiness and gumminess of the noodles, while reducing cooking loss.

Keywords: *Cassava flour, Bambara groundnut, Nutritional composition, Cooking loss*

ID: 540

Methods Used in Calculating Water Footprint in Agricultural Production

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Abstract

The water footprint in agricultural production is a critical assessment tool for the sustainable management of water resources. By analyzing the amount of water used in agricultural production, the water footprint helps enhance both environmental sustainability and economic efficiency. Water management in the agricultural sector is becoming increasingly complex due to factors such as diminishing water resources, climate change, and a growing population. Water footprint calculation methods are based on a combination of direct measurements and computed values. Factors such as irrigation methods, crop types, soil structure, and climate conditions determine water requirements. These calculations provide agricultural enterprises with opportunities to develop sustainable water management strategies. In particular, wireless sensors and remote sensing technologies enable real-time monitoring of water use, contributing to more efficient water utilization. The effective implementation of water management policies helps maintain ecosystem balances and improve agricultural sustainability. The involvement of farmers, water managers, and local communities in these processes promotes water conservation. Educational programs and awareness campaigns can ensure the implementation of proper irrigation techniques, thereby optimizing agricultural water use. In conclusion, accurately calculating and managing the water footprint in agricultural production is of great importance for the conservation of water resources and ensuring sustainable agricultural development in the future. As water efficiency increases, environmental and economic benefits can be achieved, optimizing agricultural productivity.

Key Words: *Water footprint, Agriculture, Sustainability, Climate change, Economy*

Tarımsal Üretimde Su Ayak İzinin Hesaplanmasında Kullanılan Yöntemler

Özet

Tarımsal üretimde su ayak izi, su kaynaklarının sürdürülebilir yönetimi için kritik bir değerlendirme aracıdır. Su ayak izi, tarımsal üretimde kullanılan su miktarını analiz ederek hem çevresel sürdürülebilirliği hem de ekonomik verimliliği artırmaya yardımcı olur. Tarım sektöründe su yönetimi, azalan su kaynakları, iklim değişikliği ve artan nüfus gibi faktörler nedeniyle giderek daha karmaşık hale gelmektedir. Su ayak izi hesaplama yöntemleri, doğrudan ölçümler ve hesaplanmış değerlerin kombinasyonuna dayanır. Sulama yöntemleri, bitki türleri, toprak yapısı ve iklim koşulları gibi faktörler su ihtiyacını belirler. Bu hesaplamalar, tarımsal işletmelere sürdürülebilir su yönetimi stratejileri geliştirme fırsatı sunar. Özellikle kablosuz sensörler ve uzaktan algılama teknolojileri, su kullanımının gerçek zamanlı izlenmesini sağlayarak suyun daha verimli kullanılmasına katkıda bulunur. Su yönetimi politikalarının etkin uygulanması, ekosistem dengelerinin korunmasına ve tarımsal sürdürülebilirliğin artırılmasına yardımcı olur. Çiftçilerin, su yöneticilerinin ve yerel toplulukların bu süreçlere dahil edilmesi, su tasarrufunu teşvik eder. Eğitim programları ve farkındalık kampanyaları, doğru sulama tekniklerinin uygulanmasını sağlayarak tarımsal su kullanımını optimize etmeye yardımcı olabilir. Sonuç olarak, tarımsal üretimde su ayak izinin doğru hesaplanması ve yönetilmesi, gelecekte su kaynaklarının korunması ve sürdürülebilir tarımsal kalkınmanın sağlanması açısından büyük önem taşımaktadır. Su verimliliği artırıldıkça, çevresel ve ekonomik faydalar sağlanarak tarımsal üretkenlik optimize edilebilir.

Anahtar Kelimeler: *Su ayak izi, Tarım, Sürdürülebilirlik, İklim değişikliği, Ekonomi*

Giriş

Su ayak izi, tarımsal üretimde kaynakların etkin kullanımını analiz etme amacıyla geliştirilen bir değerlendirme aracıdır. Bu kavram, tarımsal ürünlerin üretimi sürecinde kullanılan su miktarını belirleyerek, hem çevresel sürdürülebilirlik hem de ekonomik verimlilik açısından kritik bir öneme sahiptir. Tarım sektöründeki su yönetimi, su kaynaklarının giderek azalması, iklim değişikliği ve artan nüfus baskısıyla daha da karmaşık bir hale gelmiştir.

Dolayısıyla, tarımsal üretimde su ayak izinin hesaplanması, etkili su yönetimi stratejilerinin geliştirilmesine yardımcı olarak, tarımsal sürdürülebilirliği desteklemekte ve çevresel etkileri azaltmaktadır. (Batan, 2021; Tanrıverdi; Demirci, 2024)

Günümüzde, su ayak izi hesaplama yöntemleri, çeşitli çevresel, sosyo-ekonomik ve teknik faktörlere dayalı olarak şekillenmekte ve bu hesaplamalar, tarımsal işletmelere daha bilinçli ve sürdürülebilir su kullanımı sağlama imkânı sunmaktadır. Bu süreçte, su ihtiyacını belirleyen unsurlar arasında sulama yöntemleri, bitki türleri, toprak yapısı ve iklim koşulları gibi etmenler bulunmaktadır. Su ayak izinin hesaplanmasında kullanılan yöntemler, genellikle doğrudan ölçümler ve hesaplanmış değerlerin kombinasyonlarını içermektedir. Ayrıca, bu yöntemler yerel su kaynaklarının durumu ve mevcut yönetim politikalarının etkinliği gibi unsurları da göz önünde bulundurarak, tarımdaki su kullanımını optimize etmeyi amaçlamaktadır. (Ediz, 2023;Aydın, 2023; Carfi, 2022; Bağmancı, 2022)

Tarımsal üretimde su ayak izinin hesaplanması, sürdürülebilir tarım uygulamalarının geliştirilmesi için önemli bir araç olmaktadır. Bu bağlamda, çiftçiler ve tarımsal işletmeler, su kaynaklarını verimli bir biçimde kullanarak hem doğal kaynakların korunmasına katkıda bulunmakta hem de üretim süreçlerinin ekonomik sürdürülebilirliğini sağlamaktadır. İlgili yöntemlerin ve hesaplamaların etkin kullanımı, tarımsal üretimde su ayak izinin minimize edilmesine yönelik stratejilerin geliştirilmesi açısından belirleyici bir faktör teşkil etmektedir. Bu nedenle, su ayak izinin anlaşılması ve bu doğrultuda doğru yöntemlerin tercih edilmesi, gelecekte daha az su kullanarak daha fazla üretim yapma hedefinin gerçekleştirilebilmesi için elzemdir. (Çakmak & Torun, 2023; Batan, 2021; Yımam, 2023; Dikel ve Demirkale 2023; Demirci, 2024; Ağızan, 2024)

Materyal ve Yöntem

1. Su Ayak İzi Kavramı

Su ayak izi, bireylerin, toplulukların veya belirli faaliyetlerin su kullanımını ölçen bir kavramdır. Bu kavram, tarımsal üretimle ilişkilendirilmiş olduğunda, bir ürünün yetiştirilmesi, işlenmesi ve dağıtım süreçlerinde doğrudan veya dolaylı olarak harcanan su miktarını ifade eder. Su ayak izinin hesaplanması, tarım sektöründe su kaynaklarının yönetimi için kritik bir araç sağlayarak, suyun verimli ve sürdürülebilir bir biçimde kullanılmasına yönelik stratejilerin geliştirilmesine olanak tanır. Bu ölçüm, hem yüzeysel hem de yer altı su kaynaklarının tüketimini kapsamaktadır ve suyun belirli bir ürün türü için gereksinimlerini belirlemek amacıyla kullanılabilir. (Demirci, 2024; Başkılıç, 2023; Karakayaci ve Tuyluoğlu, 2022; Dikel ve Demirkale, 2023; Turgut, 2024)

Su ayak izi kavramı, çeşitli bileşenlerden oluşarak karmaşık bir yapıya bürünmektedir. Bu bileşenler arasında, tarımda kullanılan sulama yöntemleri, iklim değişkenleri, toprak özellikleri ve bitki türleri gibi faktörler yer alır. Örneğin, sulama sistemleri, suyun etkin kullanımını etkileyen en önemli unsurlardan biri haline gelirken, iklim koşulları ve çeşitliliği, ürünlerin su ihtiyaçlarını belirlemede önemli bir rol oynar. Diğer yandan, toprak yapısının da su tutma kapasitesini doğrudan etkileyerek bitkilerin su alımını etkileyebileceği gerçeği göz önünde bulundurulmalıdır. Bu durum, daha sürdürülebilir ve çevresel olarak uyumlu tarımsal uygulamaların benimsenmesi için bir temel oluşturur. (Başoğlu, 2024)

Su ayak izi, tarımsal üretim süreçlerinin su tüketimini nicel olarak değerlendirmeye yarayan önemli bir indikattır. Bu kavram, yalnızca suyun fiziksel miktarını değil, aynı zamanda su kullanımıyla ilgili çevresel etkileri ve sürdürülebilirlik açısından kritik olan faktörleri de kapsamaktadır. Tarım sektörü, su kaynaklarının etkin kullanımı açısından bu tür bir değerlendirmeyi benimseyerek, hem ekonomik verimliliği artırabilir hem de ekosistem dengesini sağlamak amacıyla gerekli adımları atabilir. Su ayak izinin doğru bir şekilde hesaplanması, su kaynaklarının üzerinde daha az baskı oluşturan tarımsal stratejilerin geliştirilmesinde hayati bir rol oynamaktadır. (Turgut, 2024; Eryılmaz, 2024; Körbalta, 2023; Ergani, 2024)

2. Tarımsal Üretimde Su Ayak İzinin Önemi

Tarımsal üretimde su ayak izinin önemi, su kaynaklarının sürdürülebilir yönetiminde kritik bir rol oynamaktadır. Su ayak izi, bir ürünün üretim süreci boyunca doğrudan ve dolaylı olarak tükettiği su miktarını nicel olarak tanımlayan bir ölçüdür. Özellikle tarımsal üretimde, bu veri çiftçilere ve politika yapıcılara, suyun daha verimli kullanılmasının yanı sıra tedarik zincirindeki her aşamada su sürdürülebilirliğini artıracak stratejiler geliştirmeleri açısından önemli bilgiler sunmaktadır. Bu bağlamda, su ayak izi analizi, iklim değişikliği gibi çevresel sorunların etkileri altında tarımsal faaliyetlerin su talebini tahmin etmek ve yönetmek için kullanılabilir. (Tanrıverdi; Demirci, 2024; Karaman, 2024; Başkılıç, 2023; Çetintaş, 2024)

Su ayak izinin tespiti, farklı tarım ürünlerinin su gereksinimlerinin anlaşılmasını sağlar; bu durum, su kısıtlılığının olduğu bölgelerde tarım uygulamalarının adaptasyonunda hayati bir araç haline gelir. Örneğin, su ayak izinin yüksek olduğu ürünlerin yerine, daha az su tüketen alternatif ürünlerin teşvik edilmesi gibi stratejiler, hem ekonomik hem de ekolojik sürdürülebilirliğe katkıda bulunabilir. Aynı zamanda, tüketici bilincinin arttığı günümüzde, su ayak izinin ölçülmesi, gıda ürünlerinin pazar değerini de etkileyen bir faktör haline gelmiştir. Bu gerekçelerle, su ayak izinin analizi yalnızca çevresel sürdürülebilirliği sağlamakla kalmaz, aynı zamanda toplum için ekonomik faydalar da oluşturur. (Turgut, 2024; Karlı & Artar, 2021; Karakayaci ve Tuyluoğlu, 2022; Karlı et al.; Boz ve Tunalioğlu, 2024)

Su ayak izinin belirlenmesi ve bu verilerin etkin kullanımı, tarımsal üretimin geleceği için kritik bir unsurdur. Daha etkin su yönetimi ve su tasarrufu uygulamaları, hem tarım sektörü için hem de genel çevre sağlığı için vazgeçilmezdir. Bu nedenle, su ayak izinin anlaşılması ve uygulanması, tarımsal üretimde su kaynaklarının korunmasına yönelik atılacak adımların temelini oluşturur ve böylece sürdürülebilir tarım uygulamalarının güçlendirilmesine zemin hazırlar. Bu süreç, yalnızca çevresel değil, ekonomik ve sosyal boyutlarıyla birlikte ele alındığında, tarımsal üretimin bütünsel bir bakış açısıyla geliştirilmesine yardımcı olmaktadır.

3. Hesaplama Yöntemleri

Hesaplama yöntemleri, tarımsal üretimde su ayak izinin kapsamlı bir şekilde ölçülmesi, analiz edilmesi ve değerlendirilmesi açısından son derece büyük bir önem taşımaktadır. Su ayak izi, belirli bir ürünün yaşam döngüsü boyunca tükettiği toplam su miktarını gösterir ve bu bağlamda çeşitlilik arz eden farklı hesaplama teknikleri kullanılmaktadır. Genel olarak, bu hesaplama yöntemleri, fizyolojik, ekolojik ve yönetsel faktörlere dayalı olarak geliştirilmiştir ve bu faktörler, tarımsal üretimdeki su kullanımını büyük ölçüde etkileyen unsurlardır. Bu yöntemler, ürün bazında, bölge bazında veya sistem bazında detaylı analizler yapılarak uygulanabilmektedir. Hesaplama yöntemleri, incelemeye tabi tutularak daha da kategorize edilebilir. Bu sayede, doğrudan yanıtlara odaklanan yaklaşımlar ile dolaylı olarak ele alınan ve daha geniş bir perspektiften bakan yöntemler şeklinde ayrıştırılmaktadır. Bu ayrım, su ayak izinin daha derinlemesine anlaşılmasını ve buna bağlı olarak daha etkili su yönetim stratejilerinin oluşturulması sürecinin mümkün hale gelmesini sağlamaktadır. Su ayak izinin belirlenmesi ve analizi, hem çevresel sürdürülebilirlik hem de tarımsal verimlilik açısından kritik bir rol oynamaktadır. (Turgut, 2024; Karlı & Artar, 2021)

Doğrudan hesaplama yöntemleri, belirli bir ürünün veya üretim sürecinin su tüketimini doğrudan ölçmeyi amaçlar ve bu yöntemler, suyun etkin bir şekilde nasıl kullanıldığını daha iyi kavramaya yardımcı olur. Bu hesaplamalar, bitkinin su ihtiyacını daha iyi anlamak için sulama uygulamaları ve doğal yağış gibi etkenlerin yanı sıra, toprak nem durumu, iklim koşulları ve sulama sisteminin verimliliği gibi çeşitli faktörleri dikkate alarak gerçekleşmektedir. Bu tür hesaplamalar genellikle, tanımlanmış su kaynakları üzerinden ve gerçek zamanlı verilerle yürütülmektedir ve bu sayede sulama uygulamalarıyla ilgili hassas bilgiler elde edilir. Dolaylı hesaplama yöntemleri ise, belirli bir ürünün su ayak izini tahmin etmek amacıyla genel verilerden yararlanarak bir tahmin süreci yürütür. Bu yöntemler, ürünün tarımsal üretiminde kullanılan toplam su miktarını hesaplamak için farklı iklim koşulları, toprak yapısı ve bitki türlerine dayanan verileri kullanarak daha geniş ve kapsamlı bir çerçevede analiz imkanı sunar. Örneğin, FAO (Food ve Agriculture Organization) tarafından geliştirilen AquaCrop modeli, bitki su stresini değerlendirirken bu tür dolaylı yöntemlere güzel bir örnek olarak öne çıkmaktadır. AquaCrop, tarımda suyun verimli bir şekilde kullanılmasına dair önemli bilgiler sağlar. Su yönetimi alanında sağladığı faydalar ile tarımsal verimliliği artırmaya yardımcı olmaktadır; böylece hem üreticilerin hem de çevrenin yararına katkıda bulunur. (Karakayaci ve Tuyluoğlu, 2022; Karlı et al.; Boz ve Tunalioğlu, 2024)

Aynı zamanda, modellerin ve hesaplama yöntemlerinin uygulanabilirliğini artırmak amacıyla, bazı yeni teknolojik gelişmelerin tarımsal üretimde su ayak izinin hesaplanmasında kullanılmaya başlandığı gözlemlenmektedir. Özellikle uydu görüntüleme, hava durumu veri entegrasyonu ve sensör teknolojisi gibi güncel araçlar, hem doğrudan hem de dolaylı yöntemlerin etkinliğini artırmakta ve daha hassas ölçümler yapılmasını sağlamaktadır. Bu tür yenilikçi yöntemler, yalnızca su kaynaklarının daha etkili bir şekilde yönetilmesine değil, aynı zamanda sürdürülebilir tarımsal uygulamalar ve stratejilerin geliştirilmesine katkı sunmaktadır. Dolayısıyla, hesaplama yöntemleri, tarımsal üretimde su ayak izinin daha iyi anlaşılmasını ve yönetilmesini sağlayan önemli ve esnek bir araç olarak karşımıza çıkmaktadır. Su yönetimi, yalnızca tarım alanında değil, su kaynaklarının yeterliliği açısından da büyük önem taşımaktadır. Tüm bu teknolojik gelişmeler, tarımsal sürdürülebilirlik hedeflerine ulaşmak için bir temel oluşturmaktadır. Ayrıca, bu gelişmelerin yanı sıra, çiftçilerin eğitimine verilen önem de artmaktadır, çünkü bilinçli ve eğitilmiş çiftçiler, daha sürdürülebilir uygulamaları benimseyerek kaynakları daha etkin kullanabilir ve su ayak izini küçültmede etkin rol oynayabilirler. Bu bütünsel yaklaşım, su yönetiminin ve tarımsal verimliliğin iyileştirilmesi için kritik öneme sahiptir. (Turgut, 2024; Karlı & Artar, 2021; Karakayaci ve Tuyluoğlu, 2022; Karlı et al.; Boz ve Tunalioğlu, 2024)

3.1. Doğrudan Ölçüm Yöntemleri

Doğrudan ölçüm yöntemleri, tarımsal üretimde su ayak izinin hesaplanmasında son derece önemli ve kritik bir yer tutmaktadır. Bu yöntemler, su kullanımını doğrudan ve belirli ölçüm teknikleriyle inceleyerek analiz eder ve tarımsal faaliyetlerin çevresel etkilerini daha net bir şekilde ve kesin bir biçimde ortaya koyar. Bu bağlamda, en yaygın doğrudan ölçüm sistemleri arasında, alan bazlı ölçümler ve bileşen bazlı analizlerle birlikte, farklı tarım uygulamalarının su tüketim profillerini güvenilir bir şekilde belirlemekte kullanılmaktadır. Bu ölçüm teknikleri, su kaynaklarının sürdürülebilir yönetimi açısından da büyük bir önem taşımaktadır. (Turgut, 2024; Karlı & Artar, 2021; Karakayacı ve Tuyluoğlu, 2022; Karlı et al.; Boz ve Tunalıoğlu, 2024)

Su tüketim ölçümleri genellikle, belirli bir zaman diliminde sulama miktarının, yağış etkisinin yanı sıra bu süreçte gerçekleşen buharlaşma kayıplarının da doğrudan kaydedilmesine dayanmaktadır. Bu tür ölçümler, çeşitli hassas sensörler ve gelişmiş cihazlar aracılığıyla gerçekleştirilir. Örneğin, toprak nem sensörleri, suyun bitki kök bölgesine ulaşma oranını ölçerken, yağış ölçerler ise, yağış miktarını doğrudan kaydedebilir. Bu ölçüm süreçleri,

bir tarımsal üretim alanında büyük önem taşır. Ayrıca, bu tür doğrudan ölçüm yöntemleri, suyun etkin yönetimi açısından kritik öneme sahiptir; çünkü bu değerli bilgiler, tarım arazilerinin sulama verimliliğini artırmaya yönelik stratejilerin geliştirilmesine olanak tanır ve böylece sulama uygulamalarının optimize edilmesine yardımcı olur. Bu sayede, çiftçiler su kaynaklarını daha verimli kullanarak maliyetlerini azaltabilirler. (Yımam, 2023; Rustamov, 2023)

Bununla birlikte, doğrudan ölçüm yöntemlerinin dezavantajları da göz önünde bulundurulmalıdır. Bu yöntemler genellikle yüksek maliyetli ekipman ve uzmanlık gerektirirken, aynı zamanda uzun dönemli veri toplama ve analiz süreçlerini de zorlaştırabilir. Bununla birlikte, bu yöntemlerin sağladığı kesin veriler, su ayak izinin değerlendirilmesinde büyük bir avantaj sunmakta ve tarımsal üretimde su kaynaklarının sürdürülebilirliğini sağlama yolunda kritik bir adım teşkil etmektedir. Sonuç olarak, doğrudan ölçüm yöntemleri, tarımsal üretimde su yönetiminin optimize edilmesine yönelik faydalı bilgiler sağlarken, çevresel etkilerin minimize edilmesi konusunda da önemli bir rol oynamaktadır. (Yımam, 2023; Başakcı, 2023)

3.2. Dolaylı Ölçüm Yöntemleri

Dolaylı ölçüm yöntemleri, tarımsal üretimde su ayak izinin hesaplanmasında ve su tüketiminin yanı sıra çevresel etkilerin değerlendirilmesinde oldukça önemli bir rol oynamaktadır. Bu yöntemler, doğrudan su kullanım verileri yerine, belirli varsayımlara ve gelişmiş modelleme tekniklerine dayanarak su ayak izini dolaylı yoldan tahmin etme sürecini içermektedir. Dolaylı ölçüm yöntemleri kapsamındaki en yaygın ve tercih edilen yaklaşım, su döngüsü ve bitkilere yönelik su tüketim kalıplarını belirleyen detaylı su hesaplama modelleridir. Bu karmaşık modeller, iklim, toprak özellikleri ve tarımsal uygulamalar gibi çeşitli etkenleri entegre ederek su ihtiyacını tahmin eder. Böylece, su ayak izinin hesaplanmasında kullanılan önemli bir veri kaynağı sağlar ve tarımda su kaynaklarının daha etkin bir şekilde yönetimine katkıda bulunur. Bu bağlamda, dolaylı ölçüm yöntemlerinin önemi, sadece tahmin yapma ile sınırlı kalmayıp, aynı zamanda sürdürülebilir tarım uygulamalarının geliştirilmesine de işaret etmektedir. (Demirci, 2024; Turgut, 2024; Sak, 2024; Ağızan, 2024)

Bunların yanı sıra, dolaylı ölçüm teknikleri, uzaktan algılama ve coğrafi bilgi sistemleri (CBS) gibi teknolojilerin entegrasyonu ile zenginleştirilmektedir. Uzaktan algılama, tarımsal alanların büyüklüğünden su varlığına; bitki sağlığından toprak nemine kadar pek çok parametreyi gözlemleme imkanı sunar. Bu tür veriler, büyük alanların kapsamlı bir şekilde değerlendirilmesine olanak tanıyarak, su ayak izinin belirlenmesinde kritik bir temel oluşturur. Ayrıca, bu yöntemler, su kaynaklarının daha verimli bir şekilde yönetilebilmesi için gerekli stratejilerin geliştirilmesine de katkıda bulunmaktadır. (Sezer ve Önder, 2024; Akpınar, 2022)

Bununla beraber, dolaylı ölçüm yöntemlerinin uygulanması, bazı sınırlamaları da beraberinde getirmektedir. Modelleme ve varsayımlar, gerçek dünyadaki karmaşık etkileşimleri yeterince temsil edemeyebilir; bu durum, hesaplamaların doğruluğunu etkileyebilir. Bu nedenle, dolaylı ölçüm sonuçlarının doğrulanması, gerektiğinde doğrudan ölçümlerle desteklenerek sağlanması önemlidir. Bu bağlamda, dolaylı ölçüm yöntemleri, tarımsal üretimde su ayak izinin hesaplanması sürecinde önemli bir yenilik sağlarken, aynı zamanda dikkatli bir uygulama ve değerlendirme gerektirmektedir. (Karakoç, 2022; Sak, 2024)

3.3. Farklı Modelleme Yöntemleri ve Teknikleri

Modelleme yöntemleri, tarımsal üretimde su ayak izinin hesaplanmasında kritik bir rol oynamaktadır ve bu süreçte önemli bir yer tutar. Bu yöntemler, özellikle su tüketim miktarının ve niteliğinin belirlenmesinde çeşitli modellerin entegrasyonunu gerektirirken, tarımsal süreçlerin dinamik yapısını anlamak için faydalı bir araç sunar. Su ayak izi hesaplamasında kullanılan başlıca modelleme yaklaşımlarından biri, su tüketiminin mekânsal ve zamansal verilerini analiz eden hidrolojik modellerdir. Bu modeller, topografya, yağış, buharlaşma ve tarımsal faaliyetlerin etkilerinin bir arada değerlendirilmesini sağlayarak daha hassas ve güvenilir tahminler yapılmasını mümkün kılar. Bu bağlamda, su ayak izinin belirlenmesi yalnızca tarımsal faaliyetlerin sürdürülebilirliğini artırmakla kalmaz, aynı zamanda çevresel etkilerini de daha iyi anlamamıza yardımcı olur. Dolayısıyla, bu modelleme yöntemleri, su kaynaklarının yönetimi ve korunması açısından son derece önemlidir. (Demirci, 2024; Adiyan, 2024; İpekçi, 2023)

Bir diğer önemli yöntem, üretim sistemlerini simüle etmeye yönelik stokastik modellemelerdir. Bu yaklaşımlar, belirsizliklerin ve değişken koşulların su tüketimi üzerindeki etkilerini daha ayrıntılı bir şekilde nicel olarak değerlendirme imkânı sunar. Zira, tarımsal üretimde iklim değişikliği gibi karmaşık dışsal faktörlerin yanı sıra, sulama yöntemlerinin etkinliği de su ayak izini önemli ölçüde etkileyebilmektedir. Dolayısıyla, bu modelleme yöntemleri, hem mevcut durumu detaylı bir şekilde analiz etmekte hem de gelecekteki olası senaryoları daha etkili bir şekilde değerlendirmekte ve sürdürülebilir su yönetimi stratejilerinin geliştirilmesinde büyük bir katkı sağlamaktadır. Bu süreç, tarımsal üretimin sürdürülebilirliğini sağlamak için kritik öneme sahiptir ve aynı zamanda su kaynaklarının daha verimli kullanılmasına yönelik öneriler sunmaktadır. (Sezer ve Önder, 2024)

Ayrıca, hayvan üretimi ve bitkisel üretim arasındaki su kullanım ilişkisini daha derinlemesine anlamak için entegre modelleme teknikleri de giderek daha fazla kullanılmaktadır. Bu yenilikçi yöntemler, farklı bitki türlerinin ve hayvan beslenme sistemlerinin su gereksinimlerini sistemli bir şekilde karşılaştırarak, suyun etkin ve verimli kullanımını optimize etmeye olanak tanır. Sonuç olarak, tarımsal üretimde su ayak izinin hesaplanmasında modelleme yöntemleri, yalnızca su tüketiminin net bir fotoğrafını sunmakla kalmamakta, aynı zamanda sürdürülebilir tarım uygulamalarının geliştirilmesinde kritik bir araç olarak öne çıkmaktadır. Bu bağlamda,

tarımsal üretimin çevresel etkilerini en aza indirmek için doğru stratejilerin belirlenmesi, bu modelleme süreçleri aracılığıyla daha etkili bir şekilde gerçekleştirilmesi mümkündür. Bu tür modellemeler, ilerleyici yöntemleri kullanarak, su kaynaklarının korunmasına katkıda bulunmakta ve tarımsal üretimde kaynak yönetimini daha sürdürülebilir hale getirmektedir. (Demirci, 2024)

3.4. Anket ve Anket Tabanlı Yöntemler

Anket ve anket tabanlı yöntemler, tarımsal üretimde su ayak izinin hesaplanmasında kritik bir rol oynamaktadır. Bu araştırma yöntemleri, özellikle çiftçiler, su yönetimi uzmanları ve tarım ekonomistleri tarafından etkili veri toplama aracı olarak sıklıkla kullanılmakta, su tüketimi ve kullanım alışkanlıklarına dair ayrıntılı ve güvenilir bilgiler sunmaktadır. Anketler, çeşitli soru türleri aracılığıyla, çiftçilerin su kullanımındaki alışkanlıklarını, su kaynaklarına erişim durumlarını ve sulama yöntemlerini daha iyi anlamakta yardımcı olur. Bu tür veriler, su ayak izinin hesaplanmasında temel bir girdi olarak kabul edilmektedir; zira su ayak izi, tarımsal ürünün üretimi sırasında kullanılan toplam su miktarını, bu suyun kaynağına göre ayrıştırarak ortaya koymayı hedefler. Dolayısıyla, bu veriler, sürdürülebilir tarım uygulamalarının geliştirilmesi ve su kaynaklarının daha verimli yönetimi için son derece önemlidir. Elde edilen bilgiler, aynı zamanda su yönetiminde stratejik kararların alınmasına da katkıda bulunmaktadır. (Çetintaş, 2024; Sak, 2024; Adiyan, 2024; İşler, 2022; Özyiğit)

Anket tabanlı yöntemlerin etkili bir şekilde kullanılabilmesi için öncelikle dikkatli, titiz ve özenli bir anket tasarımı gereklidir. Anketlerin geçerliliği ve güvenilirliği, kullanılan soru tipleri, soru cümleleri yapılarına ve anketin genel akışına bağlı olarak değişiklik göstermektedir. Açık uçlu sorular, çiftçilerin su kullanımı ile ilgili detaylı ve kapsamlı bilgi vermesini sağlarken, kapalı uçlu sorular ise belirli kategorilerde verilerin hızlı, kolay ve sistematik bir şekilde toplanmasına olanak tanır. Anket uygulamalarında aynı zamanda, örneklem büyüklüğünün dikkatlice belirlenmesi ve hedef kitle ile ilgili demografik bilgilerin toplanması, elde edilen verilerin temsil yeteneği açısından son derece ve kritik derecede önemlidir. Bu aşamada, anketin uygulanacağı coğrafi bölgeyi, tarımsal üretim türlerini ve çiftçilerin sosyo-ekonomik durumlarını göz önünde bulundurmak, sonuçlanacak verilerin daha isabetli bir şekilde yorumlanmasına zemin hazırlayacaktır. Ayrıca, katılımcıların anket sürecindeki rahatlıkları ve motivasyonları da, elde edilen verilerin kalitesini etkileyen önemli unsurlardan biri olarak değerlendirilmelidir. Bu nedenle, anketin uygulanması esnasında dikkatli bir iletişim kurmak ve katılımcılara anketin önemi ile ilgili bilgi vermek, verilerin daha güvenilir hale gelmesini sağlayabilir. (İlhan ve Deniz, 2021; İlhan ve Deniz, 2021; Öntaş et al., 2024)

Anket ve anket tabanlı yöntemler, tarımsal üretimde su ayak izinin hesaplanmasının yanı sıra, su yönetimi stratejilerinin geliştirilmesinde de faydalı bilgiler sunmaktadır. Bu tür verilerin analizi, su kaynaklarının sürdürülebilir yönetimi için gereksinim duyulan stratejilerin oluşturulmasına ve uygulanmasına katkıda bulunmakta, aynı zamanda tarımsal üretimin çevresel etkilerini değerlendirmeye olanak tanımaktadır. Uygulayıcılar, anket verilerinin mevcut tarımsal pratiklerde nasıl kullanılacağını anlamak suretiyle, su tasarrufunu teşvik eden ve daha verimli su yönetimini sağlayan politikalar geliştirebilirler. Bu bağlamda, anketlerin etkinliği yalnızca veri toplamayla sınırlı kalmayıp, aynı zamanda karar alma süreçlerinde de önemli bir araç haline gelmektedir.

Bulgular ve Tartışma

4. Yöntemlerin Etkinliği

4.1. Doğrudan Ölçüm Yöntemlerinin Avantajları ve Dezavantajları

Doğrudan ölçüm yöntemleri, su ayak izinin hesaplanmasında çeşitli avantajlar ve dezavantajlar sunmaktadır. Bu yöntemler, tarımsal üretimde su kullanımını direkt olarak ölçerek, su tüketimi ile ilgili daha kesin veriler sağlar. Gerçek zamanlı veri toplamayı mümkün kılması, tarım uygulamalarının daha iyi yönetilmesine yardımcı olur. Örneğin, bu yöntemler ile toprağın nem içeriği, sulama miktarları ve bitki su tüketimi gibi parametreler doğrudan izlenebilir. Böylelikle, kaydedilen verilerin doğruluğu, uygulanan stratejilerin etkinliğini artırabilir ve çiftçilerin kayıplarını minimize etmelerine olanak tanır.

Ancak doğrudan ölçüm yöntemlerinin, sınırlı bir uygulama alanı ve belirli dezavantajları bulunmaktadır. Öncelikle, bu yöntemlerin uygulanması maliyetli olabilir; gerekli ekipmanların temini ve kurulumu ile birlikte sürekli bakım ve kalibrasyon gerektirmeleri, ekonomik olarak sürdürülebilirliği zorlaştırabilir. Ayrıca, bu yöntemler belirli bir alan veya belirli koşullar altında uygulanabilir ve bu durum, genel geçer sonuçlar elde edilmesini engelleyebilir. Örneğin, toprak tipleri, iklim koşulları veya bitki çeşitliliği gibi değişkenler, ölçüm sonuçlarını etkileyebilir. Sonuç olarak, doğrudan ölçüm yöntemlerinin elde ettiği veriler çoğu kez belirli durumlara özgü nitelikte olabilmektedir.

Bu yöntemlerin sağladığı verilerin yanı sıra, bu verilerin analizi ve yorumlanması süreci de karmaşık bir boyut taşımaktadır. Dört mevsim ve farklı iklim koşullarında gerçekleştirilen ölçümler, değişkenler dikkate alınmadan genel ilişkilere ulaşımın önünde engel teşkil edebilir. Dolayısıyla, doğrudan ölçüm yöntemlerinin elde ettiği bulguların, bütünsel bir anlayış için dikkatli bir şekilde değerlendirilmesi gerekmektedir. Bu bağlamda, doğrudan ölçüm yöntemleri, hem hesaplamada sağladığı kesinlik hem de belirli dezavantajları ile birlikte, tarımsal üretimde su ayak izinin değerlendirilmesi konusunda önemli bir yere sahiptir.

4.2. Dolaylı Ölçüm Yöntemlerinin Avantajları ve Dezavantajları

Dolaylı ölçüm yöntemleri, tarımsal üretimde su ayak izinin hesaplanmasında oldukça önemli roller üstlenmektedir. Bu yöntemlerin temel avantajları arasında, zaman ve kaynak açısından sağladıkları verimlilik öne çıkmaktadır. Geleneksel ölçüm tekniklerinin aksine, dolaylı ölçüm yöntemleri, bitkisel su kullanımı ve toprak nemi gibi unsurları uzaktan algılama veya modelleme gibi modern teknolojilerle birleştirerek etkili sonuçlar elde edilmesini sağlar. Örneğin, uydu görüntüleri ve lokal meteorolojik tahmin modelleri, tarımsal alanlardaki su gerekliğini belirlemek için geniş ve kapsayıcı veriler sunar; bu durum, hem maliyetlerin düşürülmesine hem de tarımsal verimliliğin artırılmasına katkıda bulunur.

Öte yandan, dolaylı ölçüm yöntemlerinin bazı dezavantajları da mevcuttur. Bu yöntemlerin doğruluğu, ölçüm parametrelerine ve kullanılan teknolojik altyapıya bağlı olarak değişkenlik gösterebilir; bu durum, sonuçların güvenilirliğini sorgulatabilir. Ayrıca, bazı dolaylı ölçüm teknikleri, karmaşık algoritmalar ve modelleme süreçleri gerektirdiğinden, uzmanlaşmış bilgi birikimi ve yeterli kaynakları talep edebilir. Söz konusu yöntemlerin uygulanması sürecinde, belirli verilerin kaynaktan alınması ve uygun kalibrasyon parametrelerinin belirlenmesi gerekliliği, uygulayıcılar için ek zorluklar oluşturabilir. Dolayısıyla, bu yöntemlerin pratikteki kullanımı, bazı durumlarda ek maliyet ve iş gücü gereksinimleri doğurabilir.

Sonuç olarak, dolaylı ölçüm yöntemleri, su ayak izinin belirlenmesi sürecinde hem avantajlar hem de dezavantajlar içermektedir. Uygulayıcıların, bu yöntemlerin etkinliğini artırmak için sağlanan olanaklar ve karşılaşılabilecek zorlukları dikkatlice değerlendirmeleri gerekmektedir. Böylece, hem tarımsal üretimde su yönetiminin iyileştirilmesine hem de sürdürülebilir kaynak kullanımı hedeflerine ulaşılmasına hizmet edecek çözümler geliştirilebilir. Bu dengeli yaklaşım, dolaylı ölçüm yöntemlerinin potansiyelinden en iyi şekilde yararlanmayı mümkün kılacaktır.

4.3. Modelleme Yöntemlerinin Avantajları ve Dezavantajları

Modelleme yöntemleri, tarımsal üretimde su ayak izinin hesaplanmasında önemli bir rol oynamaktadır. Bu yöntemler, karmaşık ekosistem süreçlerini anlamada ve su kullanımının verimliliğini artırma çabalarında kritik bir araç olarak öne çıkmaktadır. Ancak, bu yöntemlerin uygulanması, hem avantajlar hem de dezavantajlar içermektedir. Avantajları arasında, tarımsal faaliyetlerin su kaynakları üzerindeki etkilerini tahmin etme yeteneği ve karar verme süreçlerini destekleme potansiyeli bulunmaktadır. Modelleme, çeşitli senaryoların simülasyonuna olanak tanıyarak, farklı su yönetimi stratejilerinin potansiyel etkilerini analiz etmeye yardımcı olur. Ayrıca, sulama tekniklerinin ve tarım politikalarının optimize edilmesini sağlayarak, su tasarrufu ve sürdürülebilirlik açısından önemli katkılar sağlar.

Bununla birlikte, modelleme yöntemleri belirli dezavantajlarla da yüz yüze kalmaktadır. Bu dezavantajlar arasında, modellerin herhangi bir gerçekliği tam olarak yansıtma kapasitesinin sınırlı olması ve veri gereksinimlerinin yüksekliği yer almaktadır. Doğru ve güvenilir çıktılar elde edebilmek için, detaylı ve kapsamlı verilere ihtiyaç vardır; bu, çoğu zaman zorlu ve maliyetli olabilir. Ayrıca, modellerin karmaşıklığı, kullanıcıların onları etkin bir biçimde değerlendirme ve uygulama yeteneklerini sınırlayabilir. Bu durum, yanlış kararların alınmasına ve kaynakların yanlış yönetilmesine neden olabilecek bir risk taşımaktadır.

Sonuç olarak, modelleme yöntemleri, tarımsal üretimde su ayak izinin hesaplanmasında avantajlı bir araç sunarken, kendi bünyesinde çeşitli zorluklar da barındırmaktadır. Tarım sektörünün, su kullanımına ilişkin doğru verilere dayanan modeller geliştirmesi ve uygulaması, su kaynaklarının yönetiminin ve korunmasının etkinliğini artırma yanında, tarımsal sürdürülebilirliği sağlamada kritik bir unsur olarak karşımıza çıkmaktadır. Bu nedenle, modelleme yöntemlerinin dikkatli bir şekilde değerlendirilmesi ve sürekli olarak güncellenmesi, su ayak izinin hesaplanmasında başarılı bir yaklaşım geliştirilmesi için elzemdir.

4.4. Anket Yöntemlerinin Avantajları ve Dezavantajları

Anket yöntemleri, tarımsal üretimde su ayak izinin hesaplanmasında geniş bir uygulama yelpazesine sahip olup, çeşitli avantajlar ve dezavantajlar içermektedir. Bu yöntemlerin en belirgin avantajlarından biri, büyük ve çeşitli bir nüfusa ulaşma yeteneği olmaktadır. Bu sayede, araştırmacılar çok sayıda veri toplayarak genel eğilimler ve kalıplar oluşturabilirler. Ayrıca, anketler, katılımcıların kendi görüşlerini ve deneyimlerini doğrudan ifade etmelerine olanak tanırken, birçok durum ve koşulu kapsayacak şekilde tasarlanabilir. Örnekleme çerçevesinin genişliği, tarımsal su kullanımında yer alan farklı faktörlerin daha iyi analiz edilmesine yardımcı olabilmektedir. Bu bağlamda, anketlerin uygulanabilirliği, zaman ve maliyet açısından da önemli bir avantaj sunmaktadır; çünkü diğer veri toplama yöntemlerine kıyasla, akıllıca tasarlanmış bir anket, hızlıca geniş bir veri seti toplayabilme potansiyeline sahiptir.

Ancak, anket yöntemlerinin dezavantajları da göz ardı edilmemelidir. Öncelikle, anketlerin yanıtlayıcıları üzerinde etkili olabilmesi için dikkatli bir biçimde hazırlanması gerekir. Eğer anket soruları belirsiz veya yanıltıcı ise, bu durum toplanan verinin güvenilirliğini olumsuz etkileyebilir. Ayrıca, anketlerin yanıt oranları, çeşitli faktörlerden etkilenerek düşebilir, bu da örneklemin temsil ediciliğini sorgulamak zorunda bırakır. Katılımcıların, su ayak izi gibi karmaşık bir konudaki bilgi seviyeleri değişkenlik gösterebileceği için, anketler zaman zaman yanıltıcı sonuçlar verebilir. Bu nedenle, anketler ile elde edilen verilerin titizlikle analiz edilmesi ve diğer veri toplama yöntemleriyle birleştirilmesi, elde edilen bulguların doğruluğunu artırmak açısından kritik öneme sahiptir. Sonuç

olarak, anket yöntemleri, su ayak izinin hesaplanmasında değerli bir araç olarak öne çıkarken, dikkatli bir planlama ve uygulama gerektirmektedir.

5. Uygulama Alanları

Uygulama alanları, tarımsal üretimde su ayak izinin hesaplanması süreçlerinin pratikte nasıl gerçekleştirildiğine dair geniş bir perspektif sunar. Su ayak izi, tarımsal ürünlerin yaşam döngüsü boyunca tüketilen su miktarını belirleyen önemli bir değerlendirme aracıdır. Bu hesaplamalar, su kaynaklarının verimli kullanımı ve sürdürülebilir tarım uygulamalarının geliştirilmesi açısından kritik öneme sahiptir. Özellikle, sulama yöntemlerinin etkinliği, ürün seçiminde suya dayalı karar verme süreçleri ve iklim değişikliğinin etkilerine karşı adaptasyon stratejileri üzerinde önemli bir etki yaratmaktadır. (Karaman, 2024; Kahriman, 2023; Dindar, 2021)

Su ayak izinin hesaplanması, farklı tarım uygulama alanlarında çeşitli biçimlerde yer bulmaktadır. Örneğin, sulama yönetimi, konvansiyonel ve organik tarım uygulamalarında su kullanımını optimize ederek, su kaynaklarının sürdürülebilir bir şekilde kullanılmasına imkan tanır. Ayrıca, ürün çeşitliliği ve yetiştirme yöntemleri, su ayak izinin minimize edilmesinde önemli bir rol oynamaktadır. Tarım işletmeleri, ürün bazında su tüketimlerini izleyerek, en az su kullanımı gerektiren türleri yetiştirmeye yönelmektedirler. Bunun yanı sıra, su ayak izi hesaplamaları sayesinde, tarımsal üretim süreçleri sürekli olarak değerlendirilmekte ve iyileştirme fırsatları ortaya konulabilmektedir. (Bulut ve Canbaz, 2022; Yımam, 2023; Muratoğlu, 2024; Demirel, 2023; Ceylan, 2024; Kalender, 2023)

Diğer yandan, su ayak izi verileri, tarımsal üretimden elde edilen ekonomik getiri ile ilişkilendirilerek, çiftçilere ekonomik sürdürülebilirlik sağlamaktadır. Çiftçiler, su ayak izini göz önünde bulundurarak, girdi maliyetlerini azaltma ve verimliliği artırma stratejileri geliştirebilirler. Ayrıca, bu ölçümler, gıda güvenliği ve tarımsal politikalara yönelik kamu politikalarının oluşturulmasında da önemli verilere zemin hazırlamaktadır. Dolayısıyla, tarımsal üretimde su ayak izinin hesaplanması, hem çevresel sürdürülebilirliğin sağlanmasında hem de ekonomik kazançların arttırılmasında kritik bir rol oynamaktadır. (Demirci, 2024; Turgut, 2024; Sak, 2024; Çakır et al.2022; Sezer ve Önder, 2024; Çetintaş, 2024; Karaman, 2024)

5.1. Tarım Sektöründe Uygulama ve Geliştirilen Yeni Yöntemler

Tarım sektörü, su ayak izinin hesaplanması uygulamalı yöntemlerinin gelişimine son derece açıktır. Su ayak izi, belirli bir ürün veya hizmetin yaşam döngüsü boyunca toplam su tüketimini belirlemeye yönelik bir kavramdır ve bu, hem üretim süreçlerinin etkinliğini artırmak hem de çevre üzerindeki olumsuz etkileri azaltmak açısından büyük önem taşımaktadır. Bu bağlamda, tarımsal üretim süreçleri, su kaynaklarının verimli, etkili ve en önemlisi sürdürülebilir bir şekilde yönetilmesinde kritik bir rol oynamaktadır. Uygulama aşamasında, çeşitli hesaplama yöntemleri ve araçları, su ayak izini belirlemek için kullanılmakta ve bu sayede hem su kullanımının optimize edilmesi sağlanmakta hem de çevresel etki analizleri daha doğru bir şekilde yapılmaktadır. Su ayak izinin hesaplanması, sürdürülebilir tarım uygulamalarının benimsenmesine ve çevresel bilincin artırılmasına yardımcı olurken, tarımsal üretim süreçlerinin genel olarak daha sürdürülebilir hale gelmesine olanak tanımaktadır. Bu nedenle, tarım sektöründe su ayak izinin doğru bir şekilde hesaplanması, gelecekteki su yönetimi stratejileri için oldukça önemli bir adım olmaktadır. (Karaman, 2024; Turgut, 2024; Karlı & Artar, 2021; Karlı et al.; İşler, 2022; Sak, 2024)

Tarım sektöründe uygulanan yöntemler arasında en yaygın olanları, su ayak izinin hesaplanmasında kullanılan çeşitli sistem dinamik modelleridir. Bu dinamik modeller, tarımsal üretim süreçlerini simüle ederek, su kullanımının farklı aşamalarını detaylı bir şekilde izleme ve analiz etme imkanı sunar. Örneğin, sulama sistemleri, toprak özellikleri, iklim koşulları ve bitki türleri gibi çeşitli faktörler, su ayak izinin hesaplanmasında kritik ve önemli bir role sahiptir. Bu faktörlerin her biri, su kaynaklarının etkin ve verimli kullanımı açısından büyük önem taşımaktadır. Ayrıca, LCA (Yaşam Döngüsü Değerlendirmesi) gibi yöntemler, ürünlerin çevresel etkilerini değerlendirirken, su ayak izinin tarımsal üretim döngüsündeki yerini daha kapsamlı ve derinlemesine anlamak için önemli bir çerçeve sunar. Bu çerçeve, çiftçilerin daha bilinçli ve sürdürülebilir su yönetimi stratejileri geliştirmelerine yardımcı olur ve böylece kaynakların daha etkin kullanımını teşvik eder. Çiftçiler, bu tür yöntemleri kullanarak, hem ekonomik hem de çevresel açıdan daha faydalı üretim metotları belirleyebilirler. (Karakoç, 2022; Sezer ve Önder, 2024; Özbek, 2023; Yavuz, 2021)

İleri düzeyde uygulamalar, su ayak izinin hesaplanmasında kablosuz sensörler ve uzaktan algılama teknolojilerinin entegrasyonunu içermektedir. Bu modern teknolojiler, su kullanımının gerçek zamanlı izlenmesine olanak tanıyarak tarım alanlarındaki su stresini daha doğru bir şekilde belirlemeye ve suyun verimliliğini artırmaya yönelik anlık veriler sunmaktadır. Bu sayede, tarım işletmeleri su kaynaklarını daha etkin bir biçimde kullanma fırsatına sahip olmanın yanı sıra, kaynakları daha verimli değerlendirmenin yollarını keşfetmekte ve uygulamaktadır. Tüm bu yöntem ve araçlar, tarım sektöründe su ayak izinin etkin bir şekilde hesaplanmasını sağlarken, aynı zamanda su kaynaklarının korunmasına yönelik önemli bir katkı sunarak gelecekteki sürdürülebilirlik hedeflerine ulaşmada yardımcı olmaktadır. Bu durum, sürdürülebilir tarımsal uygulamaların teşvik edilmesine ve bu uygulamaların yaygınlaşmasına önemli bir katkı sağlamaktadır. Dolayısıyla, tarım sektöründeki uygulamalar, su yönetimi ile çevresel sürdürülebilirliğin entegrasyonunu teşvik eden birçok fırsatı barındırmaktadır ve tüm bu süreçler, daha geniş bir perspektifte tarımsal üretkenliğin artırılmasına yardımcı

olmaktadır. Su verimliliği artırıldıkça, hem çevre hem de ekonomik açıdan önemli kazanımlar elde edilmesi mümkün olacaktır, bu da çiftçilerin ve toplumun genel yararına hizmet edecek, sürdürülebilir bir tarımsal kalkınmanın önünü açacaktır. (Çakır et al.2022; Yılmaz, 2022; Hakkı et al.2022)

5.2. Su Yönetimi Politikaları

Su yönetimi politikaları, sürdürülebilir tarımsal üretim ve su kaynaklarının etkin kullanımı için hayati öneme sahiptir. Bu politikalar, sulama sistemlerinin geliştirilmesi, su tasarrufu yöntemlerinin teşvik edilmesi ve su kalitesinin korunması gibi çeşitli boyutları içermektedir. Tarımsal üretim süreçlerinde suyun değerlendirilmesi, ürün verimliliğini artırmanın yanı sıra, potansiyel su kaynaklarını koruma açısından da kritik bir rol oynamaktadır. Su yönetimi politikaları, yerel ve ulusal düzeyde gerçekleştirilen planlama ve uygulamalarla şekillenirken, yukarıdan aşağıya ve aşağıdan yukarıya yaklaşımlar arasında bir denge sağlanmalıdır.

Su yönetiminde en iyi uygulamaların benimsenmesi, paydaşların etkin bir şekilde katılımını gerektirir. Bu bağlamda, çiftçiler, su yöneticileri ve yerel topluluklar poliçe oluşturma süreçlerine dahil edilmelidir. Eğitim programları ve farkındalık artırıcı kampanyalar, su tasarrufunun önemini vurgulamakla kalmayıp, doğru sulama tekniklerinin uygulanmasını teşvik edebilir. Ayrıca, modern teknolojilerin entegrasyonu, veri toplama ve analiz yöntemlerinin geliştirilmesi, daha bilinçli karar alma süreçlerini destekleyerek, su kaynaklarının yönetiminde önemli bir yenilikçi unsurdur. Özellikle uzaktan algılama ve veri analitiği, su tüketimini izleme ve yönetiminde önemli olanaklar sunmaktadır.

Su yönetimi politikalarının etkili bir biçimde uygulanması, sadece tarımsal üretimde su ayak izinin azaltılmasına değil, aynı zamanda ekosistem dengelerinin korunmasına da katkı sağlar. Ekonomik faktörlerin, iklim değişikliğinin ve artan nüfusun beraberinde getirdiği su stresi, bu politikaların geliştirilmesi için bir aciliyet yaratmaktadır. Uygulayıcıların, bu karmaşık dinamikleri göz önünde bulundurarak, hem yerel çözümleri hem de geniş ölçekli stratejileri dikkate alması gerekmektedir. Sonuç olarak, su yönetimi politikaları, tarımsal üretimde sürdürülebilirliği sağlamak adına kritik bir çerçeve sunmakta ve gelecekte su kaynaklarının korunması için belirleyici bir rol oynamaktadır.

5.3. Çevresel Etki Değerlendirmeleri Hakkında Ayrıntılı Bilgiler ve Analizler

Çevresel etki değerlendirmeleri, tarımsal üretimde su ayak izinin hesaplanmasında kritik bir rol oynamaktadır. Bu değerlendirmelerin temel amacı, tarımsal faaliyetlerin çevre üzerindeki potansiyel etkilerini belirlemek ve bu etkileri minimize etmek için stratejiler geliştirmektir. Su kaynakları, tarımsal üretim süreçlerinde hayati öneme sahip olduğundan, su ayak izi analizi, bu kaynakların sürdürülebilir yönetimi açısından oldukça önemlidir. Bu süreçler, çeşitli aşamalarda çevresel etki değerlendirmelerinin entegrasyonunu gerektirmeektedir. Bu bağlamda, öncelikle su tüketiminin izlenmesi, tarımsal üretim sistemlerindeki su kullanım verimliliğine dair bilgiler sağlamaktadır.

Çevresel etki değerlendirmeleri, hem nicel hem de nitel verilerin sistematik bir şekilde toplanmasını ve analiz edilmesini içermektedir. Bu değerlendirmelerin gerçekleştirilmesi, çeşitli yöntemlerin ve yaklaşımların entegrasyonunu gerektirmektedir. Örneğin, su ayak izi hesaplama yöntemleri, yaşam döngüsü analizi (LCA) ile birlikte kullanılabilmekte, böylece tarımsal ürünlerin tüm yaşam döngüsü boyunca su kullanımını değerlendirebilmektedir. Ayrıca, bu süreç içinde ekosistem hizmetleri, toprak sağlığı ve biyolojik çeşitliliğin korunması gibi faktörlerin dikkate alınması, çevresel etkilerin daha kapsamlı bir şekilde değerlendirilmesini sağlamaktadır. (Demirci, 2024; Başkılıç, 2023; Duru & Koç, 2021; Sabır et al.2023; Koç et al.2022; Karadağ, 2022)

Bu tür kapsamlı değerlendirmeler, tarımsal üretimde sürdürülebilirlik uygulamalarının geliştirilmesine olanak tanımaktadır. Dinamik bir veri toplama ve analiz süreci, tarım sektörünün su yönetimi konusunda daha bilinçli kararlar almasına rehberlik etmektedir. Çevresel etki değerlendirmeleri, sadece su kaynaklarının korunmasında değil, aynı zamanda tarımsal üretim süreçlerinin iklim değişikliğiyle adaptasyonunda da önemli bir araç olarak öne çıkmaktadır. Bu sayede, tarımsal üretim sistemleri hem verimlilik hem de çevre koruma açısından uyumlu hale getirilmektedir. Dolayısıyla, çevresel etki değerlendirmeleri, su ayak izinin doğru hesaplanmasının yanı sıra, tarımsal sürekliliğin sağlanmasında da zaruri bir unsur olarak değerlendirilmektedir.

5.4. Sürdürülebilir Tarım Uygulamaları

Sürdürülebilir tarım uygulamaları, tarımsal üretimin çevresel, sosyal ve ekonomik sürdürülebilirliğini sağlamak amacıyla geliştirilmiş yöntem ve yaklaşımlardır. Bu uygulamalar, su kaynaklarının verimli kullanılması, toprak kalitesinin korunması, biyoçeşitliliğin artırılması ve tarımsal ürünlerin sistematik bir şekilde yönetilmesi üzerine odaklanmaktadır. Su ayak izinin azaltılması, bu uygulamaların merkezinde yer alırken, tarımsal üretimde su tasarrufu sağlayan tekniklerin ve stratejilerin entegrasyonu büyük önem taşımaktadır. Örneğin, damla sulama sistemleri gibi hedefe yönelik sulama yöntemleri, su tüketimini minimize ederken, bitkilerin ihtiyaç duyduğu suyu doğrudan kök bölgesine ulaştırarak verimliliği artırmaktadır.

Sürdürülebilir tarım uygulamaları ayrıca, entegre mücadele yöntemleri kullanarak zararlılarla olan mücadelede kimyasal pestisitlerin kullanımını azaltmayı amaçlamaktadır. Doğal düşmanlar ile birlikte çalışarak ekosistem dengesini korumak, çevresel etkileri en aza indirmek ve insan sağlığını korumak yönünde önemli bir adım oluşturmaktadır. Bunun yanı sıra, organik tarım uygulamaları, kimyasal gübre ve pestisit kullanımını azaltarak,

gıda güvenliğine katkı sağlarken, doğanın döngüsel yapısına saygı gösterir. Biyodiverse tarım sistemlerinin oluşturulması, yerel bitki türlerinin teşvik edilmesi ve agroekolojik prensiplerin benimsenmesi de biyoçeşitliliği artırarak ekosistem hizmetlerinin sürdürülebilirliğine katkıda bulunur.

Sonuç olarak, sürdürülebilir tarım uygulamaları, su ayak izinin hesaplanması ve yönetilmesinde kritik bir rol oynamaktadır. Bu bağlamda, tarımsal üretim sistemlerinde çevresel ve kaynakların yönetimi açısından entegre bir yaklaşım benimsemek, tarımsal üretkenliği artırarak hem çevre hem de toplum açısından olumlu sonuçlar doğurmaktadır. Dolayısıyla, sürdürülebilir tarım uygulamaları, yalnızca mevcut kaynakların etkili kullanımıyla sınırlı kalmayıp, gelecekteki nesillerin ihtiyaçlarını da gözeten bir tarım anlayışını temsil etmektedir. Bu anlayış, hem ulusal hem de uluslararası düzeyde tarım politikalarının geliştirilmesinde önemli bir etkendir.

6. Uluslararası Uygulama Örnekleri

Uluslararası düzeyde, tarımsal üretimde su ayak izinin hesaplanmasında uygulanan çeşitli yöntemler ve örnekler, sektördeki sürdürülebilirlik standartlarının yükseltilmesi açısından önemli bir yere sahiptir. Birçok ülke, su kaynaklarının yönetimini iyileştirmek ve tarımsal üretkenliğin artışını sağlamak amacıyla su ayak izi hesaplama yöntemlerini benimsemektedir. Bu kapsamda, Hollanda, su yönetimi konusundaki yenilikçi yaklaşımlarıyla dikkat çekmektedir. Hollanda hükümeti, su ayak izinin azaltılmasına yönelik güçlendirilmiş yasa ve düzenlemeleri yürürlüğe koyarak, hem yerel hem de uluslararası düzeyde bu konuda örnek oluşturmaktadır. Ülke genelindeki tarım işletmeleri, su tüketimini izlemek ve optimize etmek için akıllı sulama sistemleri ve veri analitiği yöntemlerini kullanarak, su ayak izlerini etkili bir Biçimde Azaltma Çabası Içindedir. (Kaya ve Mazlum, 2025; Karakoç, 2022; Çakır et al.2022; Sezer ve Önder, 2024; Aydın, 2023; Demirci, 2024; Sak, 2024; Karaman, 2024; Ceylan, 2024)

Yine, Avustralya, su ayak izi hesaplama ve yönetiminde dikkat çeken bir başka örnek teşkil etmektedir. Avustralya Cumhuriyeti, tarımsal faaliyetlerde kullanılan su kaynaklarının sürdürülebilir yönetimi için kapsamlı bir üst düzey strateji geliştirmiştir. Bu strateji çerçevesinde, tarımsal su ayak izi analizleri, belirli üretim süreçleri ve su kullanımı ile ilgili verilerin toplanması ve değerlendirilmesi üzerine yoğunlaşmaktadır. Örneğin, bu ülkede uygulanan "Water Footprint Assessment" (Su Ayak İzi Değerlendirmesi) yöntemi, bireylerin, toplulukların ve işletmelerin su tüketimini belirlemekte ve kaynakların daha verimli bir şekilde kullanılmasını sağlamaktadır. Dolayısıyla, Avustralya'nın uyguladığı bu yöntemler, hem ekonomik hem de çevresel sürdürülebilirlik hedefleriyle uyumlu bir çerçevede yürütülmektedir. (Durmuşlar et al., 2023; Akçayır & Akın, 2024; Kadıoğlu, 2024; Örtlek, 2024)

Son olarak, Birleşmiş Milletler tarafından desteklenen çeşitli uluslararası projeler de tarımsal üretimde su ayak izinin hesaplanmasında küresel bir düzlemde iş birliğini teşvik etmekte ve bilgi paylaşımını kolaylaştırmaktadır. Bu projelerin amacı, gelişmekte olan ülkelerde su yönetimini güçlendirerek, su kaynaklarının etkin kullanımını sağlamaktır. Bu bağlamda, yerel tarımsal uygulamaların iyileştirilmesi ve su ayak izinin azaltılması konusunda atılan adımlar, yalnızca çevresel etkileri azaltmakla kalmayıp, aynı zamanda gıda güvenliğini artırma yönünde de somut katkılarda bulunmaktadır. Bu tür uygulamalar, envanter hazırlama, hedef belirleme ve strateji geliştirme aşamalarında diğer ülkelere örnek teşkil etmiştir. (Sak, 2024; Başoğlu, 2024; Javidroozi et al.; Karadeniz, 2024; Zahariev et al., 2024)

7. Geçmiş Çalışmaların İncelenmesi

Geçmiş çalışmalar, tarımsal üretimde su ayak izinin hesaplanmasıyla ilgili süreçlerin ve yöntemlerin evrimine dair önemli ve detaylı bilgiler sunmaktadır. Bu alandaki ilk araştırmalar, su ayak izinin tanımını netleştirmek ve ölçüm tekniklerini ve yöntemlerini daha da geliştirmek amacıyla gerçekleştirilmiştir. Özellikle, Allen ve ark. (1998), sütun su indeksinin ilk sistematik değerlendirmesini yaparak, bitki su tüketimini ve iklimsel etmenleri göz önüne alarak su ayak izi kavramını daha geniş bir çerçevede tanıtmıştır. Bu önemli çalışmalar, tarımsal verim ile su kullanımı arasındaki ilişkiyi anlamak için gerekli bir çerçeve ve temel bilgiler sunmuş ve daha sonra geliştirilen metodolojilere yönelik olarak temel bir referans noktası oluşturmuştur. Bu süreçler, günümüzdeki tarımsal uygulamaların çevresel sürdürülebilirlik açısından gelişimini de etkilemiştir. (Demirci, 2024; Yımam, 2023; Karakoç, 2022; Sak, 2024; Sandallar, 2024; Örtlek, 2024; Karaman, 2024)

Daha sonraki araştırmalarda, tarımsal ürünlerin su ayak izinin belirlenmesinde daha sofistike ve gelişmiş hesaplama yöntemleri geliştirilmiştir. Özellikle, Hoekstra ve Mekonnen (2012) tarafından yapılan çalışmalarda, su ayak izi hesaplamalarının kapsamı genişletilerek, çeşitli iklim koşullarında ve farklı ham madde türleri ile birlikte bu tür hesaplamaların nasıl yapıldığına dair detaylı bilgiler sunulmuştur. Kullanılan yöntemler, su tüketimi ve verimlilik açılarından ricat eden karmaşık bir sistem sunmakta ve bu sistemin dinamikleri, oluşan veriler üzerinden incelenmektedir. Bu bağlamda, uzaktan algılama tekniklerinin ve coğrafi bilgi sistemlerinin (CBS) entegrasyonu, daha hassas ve kapsamlı su ayak izi analizlerine olanak tanımış ve bu sayede daha doğru veriler elde edilmiştir. Böylelikle, hem tarımsal sürdürülebilirlik hem de su yönetimi stratejileri konusunda anlamlı çıkarımlar yapılmasına olanak sağlayan kapsamlı veri tabanları oluşturulmuştur. Bu veri tabanları, aynı zamanda gelecekteki analizler ve araştırmalar için de önemli bir kaynak teşkil etmektedir.

Ayrıca, çeşitli bölgelerdeki tarımsal uygulamaları inceleyen çalışmalar, farklı alanlardaki tarım uygulamalarının yerel su ayak izi hesaplamalarının çeşitli farklılıklarını ve bu farklılıkların getirdiği etkileri detaylı bir biçimde analiz etmeye yönelik önemli bulgular ortaya koymuştur. Bu tür araştırmalar, yerel su kaynaklarının mevcut

durumu, iklim iletişim değişkenlikleri ve tarımsal yöntemlerin bölgesel etkileri hakkında daha kapsamlı bir anlayış sağlamaktadır. Bu çalışmalar, yerel su kaynaklarının sürdürülebilir yönetimi için gereken yöntem ve stratejilerin geliştirilmesine de önemli bir katkı sunmaktadır. Sonuç olarak, geçmiş yıllara ait çalışmaların titizlikle incelenmesi, tarımsal üretimde su ayak izinin hesaplanmasının metodolojik verimliliğini artırmakta ve su kaynaklarının yönetimi konusundaki stratejiler ile uygulamaların geliştirilmesine büyük katkı sağlamaktadır. Geçmişe dayalı bu bilgiler, hem bilim insanlarına hem de uygulayıcılara daha etkili ve verimli su yönetimi çözümleri geliştirme hedefinde yardımcı olmakta, bu bilgiler daha iyi bir tarımsal uygulama ve sürdürülebilir bir çevre için son derece önemlidir. (Kayadibi, 2024; Fakıoğlu & Seçkin, 2023)

8. Gelecek Araştırma Alanları

Gelecek araştırma alanları, tarımsal üretimde su ayak izinin hesaplanması sürecinde önemli bir paya sahip olan çok boyutlu dinamiklerin daha kapsamlı bir şekilde incelenmesine yönelik fırsatlar sunmaktadır. Mevcut literatür, su ayak izinin belirlenmesine yönelik çeşitli yöntemler geliştirmiş olsa da, bu yöntemlerin doğruluğu ve genel geçerliliği hâlâ sorgulanmaktadır. Bu bağlamda, su ayak izi hesaplama süreçlerinde kullanılan modellerin daha yenilikçi ve parametrik yaklaşımlarla zenginleştirilmesi, ilerleyen dönemde araştırma ve uygulama alanlarının genişlemesine katkıda bulunabilir. Özellikle, iklim değişikliği ve su kaynaklarının kıtlığı gibi küresel sorunların tarımsal üretim üzerindeki etkilerinin belirlenmesi, gelecekteki araştırmaların odak noktalarından biri olmalıdır. Bu etkileşimlerin çözümlemesi, su yönetimi stratejilerinin yeniden değerlendirilmesine ve yeşil tarım uygulamalarının entegrasyonuna olanak tanıyabilir.

Aynı zamanda, su ayak izinin hesaplanmasında yerel ve bölgesel verilerin entegrasyonu da ilerleyen araştırmalar için elzemdir. Farklı coğrafi bölgelerdeki tarımsal uygulamaların su kullanımı üzerinde farklı etkileri olduğundan, bu farklılıkların göz önüne alınması gerekmektedir. Örneğin, sulama teknikleri, arazinin topografyası ve iklim koşulları gibi faktörler, su ayak izinin hesaplanmasını doğrudan etkileyen unsurlardır. Bu unsurların etkileşimlerinin detaylı bir şekilde incelenmesi, bölgesel bazda daha doğrulanmış ve uygulanabilir su yönetim stratejilerinin geliştirilmesine olanak sağlayacaktır. Ayrıca, çok disiplinli yaklaşımlar benimseyen araştırmalar, su ayak izinin sosyal, ekonomik ve çevresel etkilerini analiz ederken daha kapsamlı bir perspektif sunabilir.

Son olarak, dijital teknolojilerin ve veri analitiğinin tarımsal üretimde su ayak izinin hesaplanmasında kullanımı, gelecekteki araştırmalar için umut verici bir trend olarak öne çıkmaktadır. Uzaktan algılama, coğrafi bilgi sistemleri ve büyük veri analizi, su ayak izinin daha hassas ve gerçek zamanlı hesaplanmasını mümkün kılarak, tarımsal üretim süreçlerinin optimize edilmesine katkıda bulunabilir. Bu bağlamda, bilim ve teknoloji sinerjisinin sağlanması, su kaynaklarının daha verimli kullanılmasına ve sürdürülebilir tarım uygulamalarının teşvik edilmesine yönelik yenilikçi çözümler sunma potansiyeli taşımaktadır. Bu araştırma alanları, tarım sektörünün gelecekteki sürdürülebilirliğini güvence altına almak amacıyla hayati öneme sahiptir.

9. Sonuç

Sonuç bölümünde, tarımsal üretimde su ayak izinin hesaplanması konusundaki mevcut yöntemlerin etkinliğini ve önemini özetlemek amacıyla, başlıca bulgulara ve bu bulguların tarımsal sürdürülebilirlik üzerindeki etkilerine odaklanmak gereklidir. Su ayak izi, tarım sektöründe su tüketiminin izlenebilirliğini sağlayarak, ürün bazındaki su kullanım verimliliğini değerlendirmeye olanak tanımaktadır. Bu bağlamda, aquifer düzeyinde su tüketimi, toprak yapısı ve hava durumu gibi değişkenlerin dikkate alınması, tarımsal faaliyetlerin çevresel etkilerini anlamaya yönelik önemli bir adım teşkil etmektedir. Bu önemli ölçüm, yalnızca su kaynaklarının yönetimi açısından değil, aynı zamanda sera gazı emisyonları ve genel ekosistem üzerindeki baskılar açısından da kritik bir rol oynamaktadır.

Hesaplama yöntemlerinin çeşitliliği, her bir tarımsal ürün için spesifik koşullar ve bölgesel iklim farklılıkları göz önünde bulundurulduğunda büyük bir önem taşımaktadır. Modelleme yaklaşımı, su ayak izinin hesaplanmasında sıklıkla kullanılan bir teknik olmasına karşın, bu yöntemlerin doğruluğu ve geçerliliği yerel verilerin kalitesine bağlıdır. Matematiksel ve istatistiksel modellerin yanı sıra, saha ölçümleri ve uzaktan algılama teknolojileri de, su ayak izinin hesaplanmasında bütünleyici araçlar olarak değerlendirilmektedir. Bu çerçevede, farklı hesaplama yöntemleri arasında yapılan karşılaştırmalar, hem gelecekteki araştırmalar hem de politikaların şekillendirilmesi açısından parmak izi kimliğidir.

Sonuç olarak, tarımsal üretimde su ayak izinin hesaplanması, yalnızca su kaynaklarının korunmasını sağlamakla kalmayıp, aynı zamanda tarımsal üretkenliğin teşvik edilmesi ve iklim değişikliği ile mücadele gibi daha geniş çevresel hedeflerle de doğrudan ilişkilidir. Tarım politikalarının ve yönetim stratejilerinin, bu tür hesaplamalara dayanan verilerle desteklenmesi, su kıtlığı ile mücadele eden bölgelerde tarımsal sistemlerin sürdürülebilirliğinin artırılmasına katkı sağlayacaktır. Dolayısıyla, su ayak izi hesaplaması, tarımsal uygulamaların ekolojik ayak izini azaltmak ve gelecekteki nesillere yaşanabilir bir çevre bırakmak amacıyla kritik bir araç olarak karşımıza çıkmaktadır. (Çetintaş, 2024; Dikel ve Demirkale 2023; Aktürk ve Gültekin, 2023; Bulut ve Özer, 2024; Baysal, 2023; Dündar ve Kolay, 2021)

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Effect of Gibberellin acid on Mechanical and Morpho-physical properties of Seedless grapes

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Abstract

Gibberellic acid, a bio-regulator commercially used for berry elongation in seedless grapes. The European grape species (*Vitis vinifera* L.) is characterized by easily breakable flesh and prone to cracking in high rainfall areas. The firmness of flesh is the major determinant factor for eating quality of table grapes and firmer flesh is usually preferred by the consumers. As the grape production sector under subtropical plains is handicapped by berry cracking due to pre-monsoon showers, the present investigation was carried at Division of Fruits and Horticultural Technology, IARI, New Delhi in 2017-18 for improving the textural properties of seedless grapes through pre-harvest application of gibberellic acid (GA_3). Four different concentrations of GA_3 (20, 30, 40, 60 ppm) were applied at 20 days after full bloom stage. Five seedless grape varieties viz., Pusa Seedless, Perlette, Beauty Seedless, Pusa Trishar, and Pusa Aditi were taken for this study. The highest firmness value was obtained at 40 ppm GA_3 concentration in Pusa Aditi (5.35 N), Beauty Seedless (4.78 N), Perlette (4.13 N), Pusa Trishar (3.81 N) and Pusa Seedless (3.76 N). In cv. Pusa Seedless, the highest bunch weight (447.73 g), bunch length (21.13 cm), berry weight (1.78 g), berry length (1.58 cm) and berry diameter (1.28 cm) was obtained with 60 ppm GA_3. In cv. Perlette, the highest bunch weight (447.23 g), bunch length (19.23 cm), berry weight (2.75 g), obtained with 40 ppm GA_3, whereas maximum berry length (17.4 mm), and berry diameter (16.48 mm) was obtained with 60 ppm GA_3. In cv. Beauty Seedless, the highest bunch weight (312.76 g), bunch length (16.22 cm), berry weight (3.47 g), berry length (17.49 mm), and berry diameter (14.04 mm) was obtained with 40 ppm GA_3. In Pusa Trishar, the highest bunch weight (661.23 g), bunch length (27.34 cm), berry weight (3.45 g), berry length (17.68 mm), and berry diameter (16.33 mm) was obtained with 40 ppm GA_3. In Pusa Aditi, the highest bunch weight (520.41 g), bunch length (24.62 cm), berry weight (4.31 g), berry length (21.95 mm), and berry diameter (19.14 mm) was obtained with 40 ppm GA_3.

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Impact of zinc fertilizer on zinc content rice varieties to curve the disease status at farmer's field in Bangladesh

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Abstract

Zinc (Zn) is an essential micronutrient, that play a positive role in plant defense system to exclude the development and enzymatic reaction of different phytopathogens. Zn is responsible for sustainable plant growth by focusing the nutrient signaling and disease resistance mechanism. Zinc is also a crucial micronutrient for human health. In Asia, more than one billion peoples, specifically children and pregnant women are suffering to Zn deficiency problem. So, by producing zinc content rice variety we can reduce rice disease pressure and can fill-up our zinc requirements in human health. We did an experiment to observe the Sheath blight, Brown spot and Bacterial leaf blight disease status in farmer's field under Shirajgonj district in Bangladesh, where soil content minimum zinc level. Two zinc content rice variety BRRI dhan62 (19.8 milligram/kg), BRRI dhan72 (22.8 milligram/kg) and as a control check two non-zinc rice variety BRRI dhan52 and BRRI dhan87 were transplanted in rain fed season. Three doses of zinc fertilizer were used i) Zn present in soil 0.93 ppm (control) ii) soil test based recommended dose iii) soil test base double of recommended dose. Split-splot design and three replications were followed, where zinc fertilizer were applied in main plot and variety in subplot. We found that disease incidence (DI and Disease severity (DS) in all three diseases like Sheath blight, Brown spot and Bacterial leaf blight disease significantly lower where applied zinc double of recommended doses in rice variety BRRI dhan62 and BRRIdhan72. Disease incidence were 4% (sheath blight), 3% (Brown spot) and 5.7% (Bacterial leaf blight) in BRRI dhan72, where in BRRI dhan87 DI were 12.3% (Sheath blight), 11.7% (Brown spot) and 14% (Bacterial leaf blight) in double of recommended doses zinc treatment. Double doses recommended zinc decrease nitrogen content in all four rice varieties, but Potassium content increase in Zinc rice variety (BRRI dhan72, and BRRI dhan62) and decrease in non-zinc variety (BRRI dhan52 and BRRI dhan87) at booting stage. Zinc content were found 44.95 ppm, 50.17ppm, 52.09 ppm and 62.59ppm at BRRI dhan52, BRRI dhan87, BRRI dhan62 and BRRI dhan72, respectively at booting stage. Disease incidence and severity were minimum in BRRI dhan 72, because it contents higher zinc. Thus, it is important to cultivate zinc content rice variety and apply soil test base zinc fertilizer to reduce disease pressure for better yield and ensure sound health status.

Key wards: *Zinc, Disease severity, Disease incidence, Nitrogen, Potassium.*

ID: 543

Recent Applications in Computer Vision-based Lameness Detection of Dairy Cattles

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Abstract

Lameness is one of the three widespread disorders leads economic losses due to reduced milk and early culling in dairy industry. It affects herd productivity and animal welfare and requires effective management strategies in order to minimize its impact. Therefore, it is essential to have precise and applicability detection of lameness in dairy farming, with a focus on environmental sustainability. The visual locomotion score approach to identification of lameness in lame cows based on qualitative analysis, involving the evaluation of different combinations of bodily abnormalities, it requires observation skills and specialization used in field. The use of computer vision (CV) technology in monitoring gait and posture of dairy cattle the collection of video data on timeline is particularly suitable for rapidly diagnostics. The processes involved in determining locomotion score in CV described as follows: data collection, preprocessing, identification of body regions, extraction of features and training of classifier. This research includes, the latest developments based on computer vision in the literature which used in research and application for the detection of lameness in dairy cattle.

Key Words: *lameness, computer vision, visual locomotion score, dairy cattle, pose-estimation*

Süt Sığırlarında Topallık Tespitinde Bilgisayar Görüsü Tabanlı Güncel Uygulamalar

Özet

Topallık, süt endüstrisinde süt azalması ve erken itlaf nedeniyle ekonomik kayıplara yol açan üç yaygın bozukluktan biridir. Sürü verimliliğini ve hayvan refahını etkilemektedir ve etkisini en aza indirmek için etkili yönetim stratejileri gerektirmektedir. Bu nedenle, çevresel sürdürülebilirliğe odaklanarak süt hayvancılığında topallığın kesin ve uygulanabilir bir şekilde tespit edilmesi çok önemlidir. Topal ineklerde topallığın tespitine yönelik görsel hareket skoru yaklaşımı, bedensel anormalliklerin farklı kombinasyonların değerlendirilmesini içeren kalitatif analize dayanır, gözlem becerisi ve uzmanlık gerektirir. Süt sığırlarının yürüyüş ve duruşlarının izlenmesinde bilgisayarla görme (CV) teknolojisinin kullanılması, zaman çizelgesi üzerinde video verilerinin toplanması, hızlı teşhis için özellikle uygundur. CV'de hareket skorunun belirlenmesinde yer alan süreçler şu şekilde tanımlanmaktadır: veri toplama, ön işleme, vücut bölgelerinin tanımlanması, özelliklerin çıkarılması ve sınıflandırıcının eğitimi. Bu araştırma, süt sığırlarında topallığın tespiti için araştırma ve uygulamada kullanılan literatürdeki bilgisayarlı görmeye dayalı en son gelişmeleri içermektedir.

Anahtar Kelimeler: *topallık, bilgisayarlı görü, görsel hareket skoru, süt sığırı, duruş tahmini*

ID: 544

The Role of Biomimicry in Interior Architecture Education and Structural Forms

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Abstract

Biomimicry is an approach that aims to develop man-made systems by imitating the design principles and processes of nature. The application of biomimicry in interior architecture education allows students to develop creative thinking skills and create sustainable design solutions. This approach aims to integrate the aesthetically and functionally inspiring features of natural systems into interior design. In this context, the study examines the course content applied within the scope of Structural Knowledge, which is a compulsory course in the 3rd semester curriculum of Selçuk University Faculty of Architecture and Design, Department of Interior Architecture. Within the scope of the course, information about the structural system elements of the building, columns, beams, slabs, foundations, and the contribution of the biomimicry design approach to the design process, the structural system and the stages of shell formation are examined. The aim of the study is for students to use the principles of biomimicry to analyze the structural characteristics of structures and organisms in nature and to outline the design process in their own projects. The concept of biomimicry contributes to the development of innovative and sustainable structural forms in interior architecture education, helping them to adopt a design approach in harmony with nature. Within the scope of the study, 2nd year interior architecture students were asked to create a shell and carrier system for the interior architecture projects they worked on in the project studio within the scope of the Structural Knowledge course. As a result of the study, different shell formations and the effect of nature on the design process were emphasized. This study is expected to provide an example of the effect of the concept of biomimicry on the design process and contribute to the literature.

Keywords: *Interior Architecture, Biomimicry, Structural Forms*

İç Mimarlık Eğitiminde Biyomimikrinin Rolü ve Strüktürel Biçimler

Özet

Biyomimikri, doğanın tasarım prensiplerini ve süreçlerini taklit ederek insan yapımı sistemlerin geliştirilmesini amaçlayan bir yaklaşımdır. İç mimarlık eğitiminde, biyomimikrinin uygulanması, öğrencilerin yaratıcı düşünme becerilerini geliştirmelerine ve sürdürülebilir tasarım çözümleri oluşturmalarına olanak tanımaktadır. Bu yaklaşım, doğal sistemlerin estetik ve işlevsellik açısından ilham verici özelliklerini iç mekân tasarımına entegre etmeyi hedefler. Bu kapsamda çalışma Selçuk Üniversitesi Mimarlık ve Tasarım Fakültesi İç Mimarlık bölümü 3. Dönem müfredatında zorunlu ders olarak yer alan Strüktür Bilgisi kapsamında uygulanan ders içeriğini incelemektedir. Ders kapsamında yapının taşıyıcı sistem elemanları kolon, kiriş, döşeme, temel çeşitleri hakkında bilgileri verilmiş ve biyomimikri tasarım yaklaşımının tasarım sürecine katkısı, strüktürel sistem ve kabuk oluşumunun safhaları incelenmiştir. Çalışmada amaç öğrenciler biyomimikri prensiplerini kullanarak, doğadaki yapılar ve organizmaların strüktürel özelliklerini analiz edip, kendi projelerinde tasarım sürecnin ana hatlarını oluşturmasıdır. Biyomimikri kavramı, iç mimarlık eğitiminde yenilikçi ve sürdürülebilir strüktürel biçimlerin geliştirilmesine katkıda bulunarak, doğa ile uyumlu tasarım anlayışını benimsemelerine yardımcı olmaktadır. Çalışma kapsamına İç mimarlık 2. Sınıf öğrencilerinin, Strüktür Bilgisi dersi kapsamında proje stüdyosunda çalıştıkları iç mimari projelerine kabuk ve taşıyıcı sistem oluşturulması istenmiştir. Çalışma sonucunda ortaya çıkan farklı kabuk oluşumları ve doğanın tasarım sürecine olan etkisi öne çıkarılmıştır. Bu çalışma biyomimikri kavramının tasarım sürecinde etkisine yönelik bir örnek oluşturması ve literatüre katkı sağlaması beklenmektedir.

Anahtar Kelimeler: *İç Mimarlık, Biyomimikri, Strüktürel Biçimler*

ID: 545

Numidian fir tree (*Abies numidica*) role in the restoration of high mountain areas in Algerian forests

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Abstract

The Numidian fir tree (*Abies numidica*) can play a significant role in the restoration of high mountain areas and the colonization of limestone terrains, as well as in environmental protection. The aim of this work is to study the plant and forests of the Numidian fir tree and to explore its cultivation methods and conditions, including the propagation of this plant *in situ* (Djebel Babor) and *ex situ* (Tiner Wlad Saber Nursery in Sétif). It is important to note that micropropagation is a specialized technique that requires specific skills and adequate facilities, including a well-equipped tissue culture laboratory. We have learned from individuals involved in the project that approximately 1500 Numidian fir tree seeds were planted, and among them, 800 trees have survived and grown successfully in the Setif region. This represents an estimated success rate of 53.33%.

Keys words: Sapin Numidie, ,*Abies numidica*, Propagation, Djebel Babor.

ID: 546

Comparative Analysis of Tropical Butterfly Garden and Kalehan Ecdat Park in Konya Selçuklu District in Terms of User Preferences

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Abstract

The users of Tropical Butterfly Garden and Kalehan Ecdat Park located in Selçuklu district of Konya province were selected as the research material. Existing data on the use of urban parks were examined through a detailed literature review and survey questions were prepared to determine the demographic characteristics and park usage habits of park users in the light of the data obtained from the literature. The survey questions included demographic characteristics of users (gender, age, education level, income level and occupation). In addition, parameters such as users' preferences for park visits, the purpose of using the parks, the units and equipment required in the parks, the benefits and activities provided by the parks were also included in the evaluation. In order to examine park usage, a face-to-face survey was conducted with park users according to the Snowball technique on random weekdays and weekends, based on the law on the protection of personal data and voluntary participation. The survey was conducted with the approval of the Ethics Committee of Selçuk University, Faculty of Architecture and Design. According to Güngör 2024, the population size was calculated to obtain reliable results from the survey. Considering the population of Konya province, Selçuklu district in 2024, a survey was conducted with a 95% confidence interval and a 5% margin of error, and a total of 220 people were surveyed. The collected data were determined by Chi-Square analysis using the SPSS program. Frequency distributions, cross tabulations and statistical analysis were carried out for the survey results. The data obtained from the survey were evaluated using quantitative and qualitative analysis techniques. Quantitative data were analyzed as frequencies and percentages and the relationships between demographic characteristics and park use were examined. Qualitative data were evaluated by content analysis method and the relationships between the expectations and needs of park users and park characteristics were determined and recommendations were developed.

Key Words: *Landscape architecture, Comparative analysis, User preferences, SPSS, Konya*

ID: 547

Safety Factor in Children's Playground Design: A Research in the Case of Seydişehir National Garden

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Abstract

Children's playgrounds should be spaces that support children's interests, imagination and the development of large muscle motor skills, and are designed to allow children to move freely. There is a very special relationship between children and play; children learn, socialize, grow and develop by playing. Safety in children's playgrounds is the most important issue to be considered when designing these areas. The material of the research is the children's playground located in the National Garden in Seydişehir district of Konya province. In order to determine the problems related to security in the park, according to the Snowball technique, a face-to-face survey was conducted with the children and their parents on the basis of the law on the protection of personal data and the principle of volunteerism by going to the area on random days on weekdays and weekends. The survey was conducted with the approval of the Ethics Committee of Selçuk University, Faculty of Architecture and Design. 330 children or parents were interviewed, security problems related to the park were revealed and solutions were proposed.

Key Words: *Children playgrounds, Safety factor, Landscape design, National garden, Konya*

ID: 548

Value Added Analysis of Grape Production in Dulkadiroğlu District of Kahramanmaraş Province

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Abstract

Grapevine (*Vitis vinifera* L.), one of the oldest cultivated plants, is an economically important temperate climate plant grown in the world and in our country. Developing value-added products from grape production is a topic that needs to be brought to the agenda. However, adding value to a product or developing a new product requires a certain process. The aim of the study is to test the value-added analysis in grape production by taking the Dulkadiroğlu district of Kahramanmaraş province as an example. The primary data of the study consists of data obtained from surveys conducted in October-November 2024 with producers producing grapes in the Dulkadiroğlu district of Kahramanmaraş province. The number of sample enterprises in the study was determined according to the stratified random sampling method and the sample size was determined as 111 enterprises. According to the results of this research; it is seen that farmers are mostly members of organizations related to agricultural production. Farmers consider that agricultural organizations will be useful in benefiting from state support and aid. The Kabarcık variety, which is generally cultivated in the Dulkadiroğlu district, is mostly consumed as table grape juice, walnut sausage and bastık, as well as being consumed as table grapes. The reason for the intensive cultivation of this variety is its resistance to diseases and its ease of cultivation. In addition, Mahrabaşı, Antep Karası, Azezi, Yıldız Üzümü are among the varieties produced and evaluated as drying. A training system called serpene is used in the region at a rate of 75% and a modern high-cordon training system at a rate of 25%. The biggest problem in production is the distance to the market and transportation problems in addition to disease control. Drug dealers are mostly used in the fight against diseases and pests. In the Bertiz region, the most valuable added products produced from grapes are pekmez, walnut sausage and bastık. There are disruptions in the marketing phase of the produced products. Producers usually leave the grape pulp obtained during production and which has the potential to provide added value in an empty place in the garden. Low product prices are one of the important factors in the marketing of value-added products. Farmers believe that by ensuring branding, value-added production and demand among the public will increase. It is important to introduce high value-added products such as pekmez, walnut sausage, bastık to the world and our country and to ensure branding.

Key Words: *Viticulture, Added value, Production, Kahramanmaraş, Sustainability*

Kahramanmaraş İli Dulkadiroğlu İlçesinde Üzüm Üretiminin Katma Değer Analizi

Özet

Kültüre alınan en eski bitkilerden biri olan asma (*Vitis vinifera L.*) dünyada ve ülkemizde yetiştirilen ekonomik açıdan önemli bir ılıman iklim bitkisidir. Üzümden üretilen ürünlerden katma değerli ürün geliştirme gündeme gelmesi gereken bir konudur. Fakat bir ürüne katma değer katmak ya da yeni bir ürün geliştirmek belirli bir süreç gerektirmektedir. Bu çalışmanın amacı, üzüm üretiminde katma değer analizini Kahramanmaraş ili Dulkadiroğlu ilçesi örnek alınarak test etmektir. Çalışmanın birincil verilerini Kahramanmaraş ili Dulkadiroğlu ilçesinde üzüm üretimi yapan üreticiler ile 2024 yılı Ekim – Kasım aylarında yapılan anketlerden elde edilen veriler oluşturmaktadır. Araştırmada örnek işletmelerin sayısı tabakalı tesadüfi örnekleme yöntemine göre belirlenmiş olup örnek hacmi 111 işletme olarak belirlenmiştir. Bu araştırma sonuçlarına göre; çoğunluklu olarak çiftçilerin tarımsal üretimle ilgili organizasyonlara üye olduğu görülmektedir. Çiftçiler tarımsal örgütlerin devlet destek ve yardımlardan faydalanmada yararlı olacağını düşünmektedir. Dulkadiroğlu ilçesinde genel olarak yetiştiriciliği yapılan Kabarcık çeşidi çoğunlukla şıralık olarak değerlendirilmesinin yanı sıra sofralık, cevizli sucuk ve bastık olarak da tüketilmektedir. Bu çeşidin yoğun olarak yetiştirilmesindeki sebep hastalıklara dayanıklılığı ve yetiştiriciliğinin kolay olmasıdır. Ayrıca Mahrabaşı, Antep Karası, Azezi, Yıldız Üzümü de üretimi yapılan ve kurutmalık olarak değerlendirilen çeşitlerdendir. Bölgede %75 oranında serpene olarak adlandırılan bir terbiye sistemi, %25 oranında ise modern telli terbiye sistemi kullanılmaktadır. Üretimdeki en büyük sorun hastalık mücadelesinin yanı sıra pazara uzaklık ve ulaşım problemleri gelmektedir. Hastalık ve zararlılarla mücadele konusunda çoğunlukla ilaç bayilerinden yararlanılmaktadır. Bertiz bölgesinde üzümden üretilen katma değerli ürünlerin başında pekmez, cevizli sucuk ve bastık gelmektedir. Üretilen ürünlerin pazarlanma aşamasında aksamalar yaşanmaktadır. Üreticiler üretim sırasında elde edilen ve katma değer sağlama potansiyeli olan üzüm poslarını genellikle bahçede boş bir yere bırakmaktadır. Ürün fiyatlarının düşük olması katma değerli ürünlerin pazarlanmasındaki önemli etkenlerden bir tanesidir. Çiftçiler markalaşmanın sağlanmasıyla, katma değerli üretimin ve halk arasında talebin artacağına inanmaktadırlar. Pekmez, cevizli sucuk, bastık gibi katma değeri yüksek ürünlerin dünya ve ülkemize tanıtılması ve markalaşmanın sağlanması önem taşımaktadır.

Anahtar Kelimeler: *Bağcılık, Katma değer, Üretim, Kahramanmaraş, Sürdürülebilirlik*

ID: 549

Impact of Climate Change on Harmful Crop Insects Population

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Abstract

Climate change, resulting from environmental fluctuations and human activities, has a significant impact on agricultural pests by altering their life cycles and infestation trends. Increasing levels of greenhouse gases, high temperatures, unpredictable rainfall, and droughts affect both crops and pests. As temperatures rise, pests can develop more quickly because they receive the necessary amount of heat exposure required for their development. These weather variations influence pest growth, virulence, multiplication, persistence, and range expansion favourably, leading to more severe infestations. Crop yields depend on effective pest and disease management, which can be improved by adopting methods that consider the impact of climate change on plants and pests. In this article, we attempt to present information addressing the issues related to the impact of climate change on crop pests. The influence of basic climatic factors like greenhouse gas emission and temperature on insects are discussed, specifically about the possible effects of climate change, i.e., the gradual increase in the average temperature. The analysis reveals that pests have caused significant crop damage, leading to yield losses and posing a threat to food security. However, strategies such as proper monitoring of insect populations and their invasion patterns can help to adapt to crop health crises caused by climate change.

Key Words: *Climate change, Crop production, Pest population, Greenhouse gas, Environment*

ID: 550

Effect Of Global Alliance for Improved Nutrition (Gain) Technology Transfer on Nutritional Status of Sweet Potatoes Farmers in Oyo State Nigeria

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Abstract

The integration of new technologies by GAIN (Global Alliance for Improved Nutrition) on sweet potatoes in Nigeria is cardinal to boost the bioavailability of micronutrients, increase crop yields, promote sustainable agriculture practices, ultimately improving the nutritional status and livelihoods of farmers and their families. This study evaluates the effect of the GAIN technology transfer initiatives on the nutritional status of sweet potato farmers in Oyo State, Nigeria. A multi-stage sampling technique was used to select 234 farmers from the catchment areas of Ido, Iseyin, and Oyo West Local Government Areas. Data were collected through structured interviews and analyzed using descriptive statistics and Pearson's Product Moment Correlation. Results indicated that 71.8% of farmers were male, with a mean age of 41.5 years. Most respondents (87.2%) were married, 53.8% had at least seven years of formal education, and sweet potato farm sizes averaged 1.7 hectares. Access to extension services was high (92.3%), with frequent interactions (85.9%). Pearson's correlation revealed significant relationships between household size ($r = 0.727^*$, $p = 0.000$), frequency of contact with extension agents ($r = 0.727^*$, $p = 0.000$), and nutritional status of respondents. The study concluded that while GAIN interventions have improved production and nutrition, challenges such as high input costs and market constraints persist. The study recommended that additional agronomic practices addressing pest infestations on potato tubers should be promoted to improve post-harvest management and storage facilities.

Keywords: *Technology transfer, Orange-Fleshed Sweet Potato, food security, Biofortification, smallholder farmers, GAIN, Oyo State.*

Introduction

Agricultural development plays a fundamental role in ensuring food security, improving livelihoods, and enhancing economic stability, particularly in sub-Saharan Africa. The integration of new technologies by GAIN (Global Alliance for Improved Nutrition) on sweet potatoes in Nigeria is cardinal to boost the bioavailability of micronutrients, increase crop yields, promote sustainable agriculture practices, ultimately improving the nutritional status and livelihoods of farmers and their families. Despite Nigeria's position as one of the largest producers of sweet potatoes in Africa, smallholder farmers in Oyo State face persistent challenges that hinder productivity, market access, and income generation (Food and Agricultural Organization FAO, 2021). These challenges are compounded by limited access to improved sweet potato varieties, inadequate farming technologies, and weak value chain integration, all of which contribute to low yields and economic vulnerability (Ekanem and Nwosu, 2020).

Beyond productivity concerns, malnutrition remains a critical public health issue in Nigeria, with vitamin A deficiency (VAD) affecting approximately 30% of children under the age of five (United Nations Children's Fund UNICEF, 2022). This micronutrient deficiency leads to weakened immunity, impaired vision, and increased child mortality rates. To address this issue, the Global Alliance for Improved Nutrition (GAIN) has facilitated the introduction of the Orange-Fleshed Sweet Potato (OFSP), a biofortified crop with high levels of vitamin A, as part of broader nutrition and agricultural interventions (Bouis *et al.*, 2021). While OFSP presents a viable solution to combat both malnutrition and food insecurity, its adoption among farmers in Oyo State remains limited due to insufficient awareness, inadequate extension services, and lack of financial and infrastructural support (Agbede *et al*., 2023).

Although GAIN's technology transfer initiatives aim to improve agricultural outcomes through the provision of improved OFSP vines, training on best agronomic practices, and strengthening market linkages, there is limited empirical evidence assessing the actual impact of these interventions on farming communities in Oyo State (Global Alliance for Improved Nutrition, GAIN, 2022). The extent to which these efforts have led to increased crop yields, improved household incomes, and enhanced dietary intake of vitamin A-rich foods remains inadequately documented. Moreover, existing studies indicated that market challenges, high production costs, and a lack of policy incentives continue to undermine farmers' ability to benefit fully from biofortified crop adoption (Eze *et al*., 2020 and HarvestPlus, 2022).

Furthermore, structural barriers such as poor transportation networks, post-harvest losses, and consumer preferences for traditional sweet potato varieties have constrained the market demand for OFSP, raising concerns about the long-term sustainability of the initiative (Adepoju *et al*., 2024). Without addressing these constraints, the expected benefits of GAIN's agricultural technology transfer may not be fully realized, thereby limiting its contribution to agricultural development, rural livelihoods, and public health improvements in Nigeria.

This study, therefore, assessed the effect of the Global Alliance for Improved Nutrition (GAIN) technology transfer initiatives on the nutritional status of sweet potato farmers in Oyo State, Nigeria. Specifically, the study described the socioeconomic characteristics of the respondents. identified the technology transferred to the sweet potato farmers ,determine the effect of GAIN technology transfer on nutritional status, identified the reasons for the use of technology transferred to the respondents and investigated the constraints encountered in the use of technologies transferred to the respondents.

Methodology

The study was carried out in Oyo state Nigeria. It is bounded by the states of Kwara on the north, Osun on the east, and Ogun on the south and by the Republic of Benin on the west. Oyo state is traversed by the Yoruba Hills in the north. The state has some tropical rain forest in the south around Ibadan, the state capital, but is covered mostly by a "derived" savanna that is largely the result of clearing and burning the former forest cover to provide land for cultivation. It is inhabited mainly by the Yoruba people. The study focused on sweet potato farmers in Oyo state.The sampling procedure adopted a multi-stage approach. In the first stage, purposive sampling was used to select the three participating local government areas in Oyo State: Ido, Iseyin, and Oyo West. In the second stage, all sweet potato farmers involved in the GAIN project for potato production were purposively selected. A total of 234 sweet potato farmers participated in the study. Data collection was carried out using a well-structured interview schedule designed in alignment with the research objectives. The study measured both dependent and independent variables. The dependent variable, was the effect of GAIN technology transfer on nutritional status of sweet potato farmers. Statements related to effects generated were scored using a four-point rating scale: high effect (3), moderate effect (2), low effect (1), and no effect (0).The independent variables included the respondents' age, years spent in school and so on. Descriptive statistics, including frequency counts, percentages, mean, and weighted mean scores, were used to summarize and interpret the data. To test the research hypothesis and determine the relationship between variables, Pearson Product Moment Correlation was applied as the inferential statistical tool.

Results And Discussion

In Table 1, a majority (71.8%) of the respondents were male, while 28.2% were female, indicating significant male involvement in sweet potato production on GAIN project. This aligns with findings from Aboajah and Ekeledo (2024), who reported that 70.8% of males participated in land preparation activities for sweet potato farming in Anambra State. The predominance of male participation may be attributed to the labor-intensive nature of certain farming activities

Regarding age distribution, nearly 60.0% of respondents were between 31 and 50 years old, with a mean age of 41.5 years, suggesting that the farmers were in their economically active years. This is consistent with Egwuonwu and Ozor (2020), who found an average age of 35.5 years among sweet potato farmers in Imo State, indicating that sweet potato farming is predominantly undertaken by individuals in their productive age bracket. Marital status analysis revealed that 87.2% of the respondents were married, implying a high level of social responsibility among the farmers. This finding is in line with Egwuonwu and Ozor (2020), who reported that 65.0% of sweet potato farmers in Imo State were married, suggesting that marital status may influence farmers' commitment to agricultural activities.

In terms of education, more than half (53.8%) of the respondents had between 7 and 12 years of schooling, while 33.3% had more than 12 years of formal education. This suggests a relatively high literacy level among the farmers, which can facilitate the adoption of improved agricultural technologies. Egwuonwu and Ozor (2020) found that 51.6% of sweet potato farmers in Imo State were literate, highlighting the role of education in enhancing farmers' ability to adopt new technologies.

The average household size among respondents was six members, with 60.3% having between 5 and 8 members. Larger household sizes may provide additional labor for farming activities, potentially influencing the scale of sweet potato cultivation. This observation is supported by Aboajah and Ekeledo (2024), who noted that household size significantly affects gender participation in sweet potato farming activities.

Farm size analysis indicated that 46.2% and 41.0% of respondents cultivated 1 and 2 hectares, respectively, with a mean farm size of 1.7 hectares. This suggests a moderate scale of sweet potato production among the farmers. Egwuonwu and Ozor (2020) reported an average farm size of 1.1 hectares among sweet potato farmers in Imo State, indicating that small to medium-scale farming is common in sweet potato production. Regarding farming experience, 75.6% of respondents had more than two years of experience in sweet potato production, with a mean of 3.2 years. This level of experience may be beneficial in adopting and implementing improved farming practices. Kolawole et al. (2017) emphasized that farming experience is a significant determinant of adopting improved sweet potato technologies in Kwara State.

Table1: Distribution of respondents according to socio-economic characteristics of the respondents n=234

Socioeconomic characteristics	Frequency	Percentage	Mean	
Sex				
Male	168	71.8		
Female	66	28.2		
Age (Years)				
≤ 30	48	20.5		41.6
31-50	135	57.7		
Above 50	51	21.8		
Marital status				
Single	21	9.0		
Married	204	87.2		
Divorce	3	1.3		
Separated	6	2.6		
Religion				
Christianity	144	61.5		
Islam	78	33.3		
Traditional	12	5.1		
Years spent in school				
No formal education	9	3.8		
≤ 6	21	8.9		12.0
7-12	126	53.8		
Above 12	78	33.3		
Household size				
≤4	54	23.1	6	
5-8	141	60.3		
Above 8	39	16.6		
Farm size (hectares)				
1	108	46.2	1.7	
2	96	41.0		
3	30	12.8		
Years of experience in farming				
≤2	57	24.4	3.2	
Above 2	177	75.6		
Contact with GAIN extension agent				
Yes	216	92.3		
No	18	7.7		
Frequency of contact with GAIN extension agent				
Weekly	6	2.6		
Fortnightly	201	85.9		
Monthly	3	1.3		
Yearly	24	10.3		

Source: Field survey, 2024

Access to extension services was reported by 92.3% of respondents, highlighting the importance of extension agents in disseminating agricultural innovations. Egwuonwu and Ozor (2020) found that 61.7% of sweet potato farmers in Imo State had contact with extension officers, underscoring the role of extension services in facilitating technology adoption. The frequency of contact with extension agents varied, with 85.9% of respondents reporting fortnightly interactions. Regular engagement with extension services can enhance farmers' knowledge and adoption of improved practices. Aboajah and Ekeledo (2024) recommended that research and extension should focus on both male and female sweet potato farmers with appropriate techniques to improve participation and enhance income and standard of living.

Effect of GAIN Technologies Transferred to Sweet Potato Farmers

Table 2 presents the effects of GAIN technologies on the nutritional status of sweet potato farmers. The results indicated that the increased consumption of nutrient-rich "Solo Gold" potatoes and the perceived improvement in overall health due to the consumption of nutritious "King J" potatoes were ranked highest, both with a WMS of 2.7. This finding aligns with Low *et al*. (2017), who reported that biofortified sweet potato varieties significantly enhance household nutrition and vitamin A intake, particularly in rural farming communities.

A notable increase in income from "Solo Gold" production, which enabled farmers to purchase a wider variety of nutritious foods, and the production of vitamin- and mineral-rich potatoes were ranked third, each with a WMS of 2.6. This is consistent with the findings of Thiele *et al*. (2020), who highlighted that improved sweet potato varieties contribute to higher yields and better market opportunities, thereby increasing farm incomes.

Training provided by GAIN improved farmers' knowledge of the nutritional value of the "Mother's Delight" variety, with a positive impact on household nutrition. This, along with farmers' willingness to recommend the variety to others, was ranked fifth (WMS = 2.5). Studies by Andrade et al. (2016) suggest that farmer training programs on biofortified crops enhance knowledge adoption, leading to better agronomic practices and higher acceptance of new varieties. Additionally, the production of high-yield, nutrient-dense potatoes was ranked seventh (WMS = 2.2), supporting evidence from Mwanga *et al.* (2017) that improved sweet potato varieties have superior agronomic and nutritional benefits.

Farmers acknowledged that the technology transfer improved their ability to cultivate a diverse range of potatoes and enhanced their understanding of essential micronutrients, both ranking eighth with a WMS of 2.0. However, post-harvest loss reduction ranked the lowest (WMS = 1.8), suggesting that this aspect of production still requires improvement. This finding aligns with Tumwegamire *et al.* (2018), who noted that post-harvest losses remain a major challenge for sweet potato farmers despite the adoption of improved varieties.

Reasons for the usage of GAIN Technologies on sweet potatoes

Table 3 presents the factors influencing the adoption of GAIN technology among sweet potato farmers. The findings indicate that all respondents (100%) identified high tuber yield, early maturity, tuber color, high vine yield, ease of access to the introduced technology, and access to extension agents as key determinants of adoption. These results suggest that the perceived agronomic and economic benefits of GAIN technology play a crucial role in its uptake. This aligns with Rogers' (2003) Diffusion of Innovation Theory, which posits that the relative advantage of a technology significantly influences its adoption.

Moreover, 84.6% of respondents highlighted the provision of market access as a critical factor, reinforcing the argument by Omonona *et al.* (2019) that reliable market opportunities enhance farmers' willingness to adopt improved agricultural technologies. Additionally, 66.7% and 60.3% of respondents identified good culinary quality and pest and disease resistance, respectively, as motivations for adoption. This is consistent with Abdoulaye *et al.* (2014), who emphasized that consumer preferences and resistance to biotic stress are key determinants of technology uptake in smallholder farming systems. Furthermore, 41.0% of farmers indicated that drought resistance was an important factor, while 26.9% considered high dry matter content significant. These findings are in agreement with Simtowe et al. (2021), who established that the environmental adaptability and nutritional attributes of improved crop varieties influence farmers' usage decisions.

GAIN Agricultural Technologies Transferred to Sweet Potato Farmers

Table 4 presents the GAIN agricultural technologies transferred to sweet potato farmers in the study area. The findings indicated that all respondents (100%) reported receiving improved sweet potato varieties, including Mother Delights (yellow), Solo Gold (pink), and King J (pink), alongside recommended agronomic practices such as correct spacing (30 cm × 30 cm) and the use of 2–3 node cuttings. These results suggest that GAIN extension services prioritize both varietal improvement and best agronomic practices, aligning with findings by Low et al. (2017), which highlight the role of improved crop varieties in enhancing smallholder productivity.

Furthermore, 84.6% and 73.1% of respondents indicated receiving training on the application of liquid fertilizer and the use of vines from vine multipliers, respectively, reflecting the importance of soil fertility management and quality planting materials in sweet potato production. This aligns with Abidin et al. (2015), who emphasized that the availability of certified planting materials significantly enhances yield and disease resistance.

In addition, 39.7% of farmers reported adopting the 75 cm × 75 cm ridge planting method, and 37.2% utilized insecticides, fungicides, and tractors for cultivation. The relatively lower adoption rates for mechanized farming and chemical pest control may indicate financial or infrastructural constraints, consistent with studies by Gurmu et al. (2020), which found that resource limitations often hinder smallholder farmers from fully integrating modern agricultural technologies.

Table 2: Distribution of respondents according to effect of GAIN technologies transferred to the sweet potato farmers

*Effect of the GAIN technologies transferred on sweet potato farmers nutritional status	WMS	Rank
There is increase in consumption of nutrient-rich "solo gold" potatoes since adopting the GAIN technology	2.7	1st
GAIN technology transfer has helped me to produce a more diverse range of potatoes, improving my family's access to essential micronutrients	2.0	8th
My family noticed an improvement in my overall health and wellbeing, which attributed to the increased consumption of nutritious "king J" potatoes	2.7	1st
The training received from GAIN enabled me to make informed decisions about the nutritional value of "mothers delight" sweet potato variety	2.5	5th
Through GAIN technologies, there is considerable production of potatoes with higher yields and better nutritional content, which has improved my family's nutrition status	2.2	7th
The technology transfer project has helped to reduce post-harvest losses, resulting in more potatoes available for consumption and improved nutrition for the family	1.8	10th
There is significant increase in income since adopting the production of "Solo gold", which has enabled me to purchase a more diverse range of nutritious foods for the family	2.6	3rd
The technology transfer project has empowered me to take control of my nutrition and make informed decisions about the food I grow and consume	2.0	8th
There is production of the new potatoes that are rich in essential vitamins and minerals, improving family's overall nutrition status	2.6	3rd
Production of "mothers delight" has had a positive impact on family's nutrition status, and I would recommend it to other farmers	2.5	5th

Source: Field survey, 2024**WMS:** Weighted Mean Score

Table 3: Distribution of respondents according to reasons for the use of GAIN agricultural technology transferred

* Reasons for the use of GAIN technology transferred	Frequency	Percentage
High tuber yield of varieties	234	100.0
Good culinary test	156	66.7
Early maturity of varieties given	234	100.0
High dry matter of tuber	63	26.9
Colour of tuber	234	100.0
Drought resistant varieties	96	41.0
Disease and pest tolerant	141	60.3
High vine yield	234	100.0
Ease of access to technology introduced	234	100.0
Provision of market for sweet potato cultivated by GAIN	198	84.6
Access to extension agents from GAIN	234	100.0

Source: Field survey, 2024
*: Multiple responses

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Table 4 Distribution of respondents according to technologies transferred to respondents in the study area

*Technologies Transferred	Frequency	Percentage
Mother delights variety (Yellow in colour)	234	100.0
Solo gold variety (Pink in colour)	234	100.0
King J variety (Pink in colour)	234	100.0
Correct spacing (30-30cm apart)	234	100.0
Application of liquid fertilizer	198	84.6
2-3 node cuttings inserted into the soil	234	100.0
Use of vines from vine multiplier	171	73.1
Use of insecticide/fungicide	87	37.2
Use of tractors for cultivation	87	37.2
75cm x 75cm on ridges	93	39.7

Source: Field survey, 2024
***:** Multiple responses

Severity of constraints encountered in the use of GAIN agricultural technology transferred to sweet potato farmers

Table 5 presents the severity of constraints affecting the adoption of GAIN agricultural technologies among sweet potato farmers in the study area. The results indicate that poor storage facilities and millipede and centipede infestations were the most significant challenges, each with a weighted mean score (WMS) of 3.0. This suggests that post-harvest loss management remains a critical issue despite the introduction of GAIN technologies. Tuber rot disease ranked third, with a WMS of 2.7, while the high cost of recommended liquid fertilizer and excessive water content in potato tubers followed, both with a WMS of 2.6. These findings highlight financial constraints as a major impediment to the full implementation of GAIN technologies. Furthermore, inadequate market access (WMS = 2.3) and low income from sweet potato cultivation (WMS = 2.1) were identified as additional constraints. Poor extension education on sweet potato production ranked the lowest, with a WMS of 1.1, indicating a potential gap in knowledge dissemination.

Table 5. Distribution of respondents according to severity of constraints encountered in the use of GAIN agricultural technology transferred in the study area

Severity of constraints encountered in the use of GAIN technology transferred	WMS	Rank
High cost of recommended liquid fertilizer	2.6	4th
Tuber rot disease	2.7	3rd
Inadequate access to market	2.3	6th
Millipede and Centipede infestation (pest)	3.0	1st
Poor income from sweet potato cultivation	2.1	7th
Poor extension education on sweet potato production	1.1	8th
High water content in the potato tuber	2.6	4th
Poor storage facilities	3.0	1st

Source: Field survey, 2024
F: Frequency
%: Percentage
WMS: Weighted Mean Score

The result in table 5 revealed that that household size (r = -0.727*, p = 0.000) and frequency of contact with extension agents (r = 0.727*, p = 0.000) were significantly related to the effect of GAIN technologies. These findings suggested that larger household sizes attracted lower nutritional status of farmers. Additionally, frequent interactions with GAIN extension agents enhance farmers' ability to utilize the technologies effectively, leading to improved production and nutritional status.

Table 5: PPMC showing significant relationship between the selected socioeconomic characteristics of respondents and effect of GAIN technology transferred on sweet potato farmer's nutritional status

Socioeconomic characteristics	Correlation Coefficient	P-value	Remark
Age	0.039	0.735	Not Significant
Years spent in school	0.094	0.413	Not Significant
Household size	0.764*	0.000	Significant
Frequency of contact with GAIN extension agents	0.348*	0.000	Significant
Years of farming experience	0.004	0.974	Not Significant

Source: Computed data, (2024)

Conclusion And Recommendations

This study concluded that GAIN technologies transferred on sweet potatoes have significantly benefited sweet potato farmers by enhancing their nutritional status. The usage of GAIN technologies was influenced by reasons such as high tuber yield, early maturity, and ease of access to improved varieties. Key technologies received and utilized included the Mother Delights, Solo Gold, and King J sweet potato varieties, along with recommended agronomic practices. However, farmers faced challenges such as poor storage facilities and pest infestations. The study recommended that additional agronomic practices addressing pest infestations on potato tubers should be promoted to improve post-harvest management and storage facilities.

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AI and IoT-Based Smart Irrigation: A Review of Challenges and Future Trends

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Abstract

Artificial Intelligence (AI) and Internet of Things (IoT) integration has established a new generation of intelligent irrigation systems that deliver sustainable water management solutions to address world water scarcity problems and agricultural requirements. This literature review presents an analysis of the present situation and obstacles alongside emerging trends of AI and IoT-based smart irrigation systems supported by international examples and technological milestones. Physical water conservation through AI-driven irrigation systems combined with IoT sensor surveillance and drone monitoring results in 20-35% water savings at the same time as improved yield outcomes across Australian regions together with Indian and Spanish territories. The wide use of smart irrigation systems is limited by technical difficulties that prevent rural Africa from connecting by economic pressures on poor farmers and by ethical challenges with European data security. The deployment become challenging because of scalability issues and maintenance problems that affect different farming ecosystems. The development of emerging technologies like edge computing, blockchain, and 5G, together with solar-powered IoT systems, provides solutions alongside research efforts toward energy-efficient climate-friendly designs. A comprehensive review combines current evidence into two major parts to evaluate its impacts on farmers, policymakers, and researchers. The review also shows where scalability and accessibility remain limited. The success of AI and IoT precision farming technology relies on cooperative work between multiple fields of study together with equal policies that support their implementation. Time must be dedicated to resolving these problems because smart irrigation systems need to fulfill worldwide food security along with sustainable development targets.

Key words: AI-driven irrigation, IoT sensors, smart agriculture, precision irrigation, water management, blockchain in agriculture, edge computing, renewable energy irrigation

1.1 Introduction

Agriculture stands as the foundational element of worldwide food security, although its operation suffers from major problems because of growing populations joined with climate shifts and evaporating freshwater availability. A 40% water deficit exists in the global water supply estimation for 2050, while irrigation utilizes about 70% of worldwide freshwater withdrawals. The standard irrigation techniques present difficulties because they neither successfully optimize agricultural production nor protect the environment efficiently. The combination of Artificial Intelligence (AI) systems operating with Internet of Things (IoT) devices makes up a revolutionary irrigation solution under the name of smart irrigation. Having IoT devices monitor environmental parameters gives AI systems the ability to manage water consumption efficiently and determine irrigation requirements and guide decision-making processes. This combined technology approach will direct farming operations into a new exacting direction which brings sustainable water management practices alongside higher agricultural output.

1.2 Objectives of the Review

The review examines existing knowledge about AI and IoT-based smart irrigation systems which focuses on their applications together with their limitations as well as future potential. This paper examines three essential aspects regarding AI and IoT applications in irrigation practices: (1) describes current integration methods, (2) describes key barriers affecting adoption, and (3) investigates emerging models for future smart irrigation systems. Through this combined technical and practical approach, this study provides essential information for researchers, practitioners and officials who work in agriculture technology fields.

1.3 Scope and Methodology

This review investigates AI and IoT applications in irrigation management while not addressing broader agricultural applications except when they directly touch irrigation systems. The review examines recent research from peer-reviewed journals, conference materials, and technical reports that originate mainly from IEEE Xplore, Scopus, and Google Scholar databases during the previous ten years. The search for relevant literature relied on the selected keywords “AI in irrigation,” “IoT smart irrigation,” “precision agriculture,” and “water management technologies.” The study included research papers about AI-IoT integration challenges and innovations and future direction works that maintained a focused relevant analysis. The analysis focuses on worldwide ideas that

additionally respect geographical differences between various agricultural tech acceptance and farming requirements.

2. Overview of AI and IoT in Smart Irrigation

2.1 Core Concepts

Two major functions guide smart irrigation technology through the integration of Artificial Intelligence (AI) and the Internet of Things (IoT). These functions include the acquisition of data and the implementation of intelligent decision systems. IoT consists of networked objects including sensors that monitor ground moisture and weather monitoring systems and controllers which share information through wireless communication networks (Selvam & Al-Humairi, 2023). The established monitoring infrastructure tracks vital measurements including soil water levels together with environmental humidity and prediction of rain events. AI-operated algorithms consisting of ML and DL generate insights from the processed data (Rane, *et al.,* 2024). AI analyzes weather data in combination with plant water needs to establish ideal irrigation timing which leads to better water use efficiency and reduced wastage. The combination of these technologies operates in a self-contained system which dynamically responds to environmental changes thus making smart irrigation differ from conventional approaches.

2.2 Evolution of Smart Irrigation Systems

The techniques of irrigation have experienced drastic changes as human-operated flood irrigation systems evolved to technology-powered automated irrigation systems. The early development of irrigation technology integrated timer-based sprinklers and drip irrigation yet did not offer adjustable controls (Tripathi, 2022). The early development of IoT in the 2000s enabled farmers to use mobile device connectivity for monitoring sensors which helped them modify irrigation routines. Prediction technology and automation have brought AI systems into the current irrigation development. AI-IoT combines to minimize water consumption by 30% better than traditional techniques yet produces equal or better production results (Senoo *et al.,* 2024). Precision agriculture represents the dominant movement in which resource management becomes the most critical aspect.

2.3 Key Components

The functionality of AI and IoT-based smart irrigation systems depends on various hardware and software collaborative elements. Low-power IoT devices like capacitive soil moisture sensors and weather stations together with solenoid valves constitute hardware components (Shamsudeen, 2021). These devices operate on solar-powered batteries to maintain sustainability for distant locations. Cloud platforms collect IoT network data through software components where AI algorithms execute data analysis to create irrigation strategies beginning with basic regression models and ending with neural networks (Preite & Vignali, 2024). The components of an irrigation system use ZigBee and LoRaWAN and Wi-Fi communication protocols to transfer data effectively (Dhatterwal, *et al.,* 2024). The system's scalable design operates well due to reliable connections between its parts while ensuring software interoperability.

3. Current State of Research

3.1 Applications of AI and IoT in Irrigation

AI and IoT applications for smart irrigation systems are widely adopted by international agricultural sectors to suit various needs within different climate zones and economic ranges. The precision irrigation system serves as a primary use case that uses IoT devices with Artificial Intelligence algorithms for delivering precise water dispensations to targeted plant areas at correct times. This prevents irrigation water from going to waste. The adoption of these systems within Middle Eastern arid regions enables optimal date palm management through decreased water requirements by 25% according to (Alnaim *et al.,* 2022). The combination of IoT data from meteorological measurements with AI forecasting models enables water scheduling through weather-based methods which yields good results in Asian regions dependent on monsoons (Indira *et al.,* 2023). Soil and crop monitoring uses IoT multispectral sensors to collect data which machine learning processes for agricultural evaluation in both large-scale North American maize fields and Southeast Asian rice paddies (Solano Correa, 2025). The range of agricultural settings which proves the flexibility of AI-IoT solutions includes high-tech European commercial operations in addition to Sub-Saharan African areas with limited resources.

3.2 Notable Case Studies

Zone irrigation and collective irrigation programs benefit from real-world practices of AI and IoT technologies in irrigation management. The Murray-Darling Basin conducted an IoT and AI decision support system pilot project that cut water usage by 35% without affecting cotton production rates (Parr *et al.,* 2022). The Tamil Nadu Agricultural University in India built a low-cost IoT-AI system for drip irrigation and this technology enhanced rice production by 20% while attracting use from small farmer community (Ahmad & Nabi, 2021). AI enabled Spanish vineyards to increase their water efficiency rate by 30% through European Union backing for IoT data analysis (Linaza, et al., 2021). A Kenyan research study demonstrated limited water savings of 15% because of connectivity issues despite conducting the study in the region (Karuku, 2018). This showed discrepancies in local infrastructure development. The implementation examples demonstrate the capacity for and inconsistent advancement rates of smart irrigation systems worldwide.

3.3 Technological Advancements

AI together with IoT functionalities have received major enhancements in recent times. The development of sensor technology now includes affordable yet precise devices such as capacitive soil moisture sensors made by China which are currently deployed across Asia and Africa (Aarif KO *et al.,* 2024)]. Deep learning models enable artificial intelligence to predict irrigation requirements precisely which is apparent through studies that used neural networks in Brazilian soybean fields (Baio *et al.,* 202)]. Large-scale monitoring became possible through the data fusion of IoT information and satellite images and drones particularly in Canada's prairie farming region (Sishodia *et al.,* 2020). Cloud-based platforms operating in Japan and Germany use mobile apps to allow real-time processing and connect farmers to database resources (Zhang, 2024). Smart irrigation technologies continue to advance worldwide due to local research communities who work across multiple continents.

4. Challenges in AI and IoT-Based Smart Irrigation

4.1 Technical Challenges

The implementation of AI and IoT technologies for smart irrigation systems encounters substantial technological challenges in different areas and infrastructure networks. Sensor-driven data accuracy represents a crucial problem because environmental elements including dust in North African deserts and tropical Southeast Asian moisture can compromise sensor performance (Gualtieri, *et al.,* 2024). The connectivity issue is a major problem in regions with limited internet access like Sub-Saharan Africa since the area suffers from poor cellular network coverage that disrupts IoT data transmission (Onsomu, *et al.,* 2024). The high demands for data processing capacity from AI models create operational problems for developing countries because they do not have strong computing infrastructure or cloud access (Rehan, 2024). Research conducted in India showed real-time processing delays decreased irrigation efficiency by 15% in regions restricted by limited resources according to available findings (Nsoh, *et al.,* 2024). The technical obstacles serve as evidence that flexible systems that work well for different worldwide environments need to be developed.

4.2 Economic and Adoption Barriers

The integration of AI-IoT irrigation systems faces scalability limitations because of economic obstacles and challenges with adoption mainly affecting low-income agricultural economic settings. Poorest communities especially struggle to afford investment costs in IoT hardware coupled with AI software that can reach thousands of dollars per unit of cultivated land (Hambye & Desmet, 2021). Government aid programs in Latin American regions struggle to promote AI-IoT irrigation systems adoption because both maintenance costs and technical illiteracy prevent rural area adoption (McCarthy, *et al.,* 2024). The survey conducted in Eastern Europe revealed that 60% of farmers showed ignorance regarding smart irrigation advantages as they maintained a preference for traditional irrigation practices (Ricart & Rico-Amorós, 2021). Wealthier regions with technical proficiency such as North America as well as Western Europe receive the majority of digital technology uptake because of economic and social factors that create a divide between communities.

4.3 Environmental and Ethical Concerns

AI and IoT irrigation systems produce environmental as well as ethical concerns in addition to technical and economic challenges. The energy usage of IoT devices and AI computing requires significant power consumption that leads to carbon emission problems identified as main sustainability concerns in Scandinavia (Ruilova Alfaro, 2024). Data privacy poses an ethical problem for EU farmers since they are worried IoT devices transmit their information to external organizations under GDPR (Ryan *et al.,* 2024). The implementation of technology has encroached upon traditional farming wisdom in indigenous areas across Australia and South America, causing concern about cultural heritage maintenance (Bellwood, 2022). A fair balance needs to be established that connects smart irrigation systems to worldwide sustainability and fairness goals.

4.4 Scalability and System Maintenance Challenges

The deployment of AI and IoT irrigation systems on a large scale after successful tests faces logistical obstacles that become more difficult due to required maintenance work. Scalability is restricted because agricultural systems with different landscape variations prevent systems from successfully being implemented across multiple agricultural areas (Salpina, 2020). The Chinese national smart irrigation program encountered interoperability problems between different provinces because its IoT protocols remained unstandardized (Zeng *et al.,* 2025). Adoption becomes more difficult because remote areas like rural Mongolia and the Andean highlands lack technical support, while sensors and devices need regular maintenance procedures (Orlove *et al.,* 2024). A South African examination uncovered that 40% of IoT irrigation systems stopped functioning after two years because of poor maintenance practices, which underlines the requirement for such systems to have durable life cycles and low-maintenance provisions (Alharbi *et al.,* 2024). Smart irrigation faces sustainability threats throughout its extended application because of various obstacles that specifically affect resource-constrained and diverse agricultural regions.

5. Future Trends and Innovations

5.1 Emerging Technologies and Innovations

Smart irrigation with AI and IoT deployed by the following technological advancements will increase the efficiency and global adaptation of this system. Implementing AI predictive models equipped with deep learning

and machine learning functions enables precise water need forecasting to control irrigation timings. Brazilian soybean automation through neural networks cut water consumption by 20% in a solution suitable for Southern African rural areas (Silva *et al.,* 2024). The use of UAVs (drones) in crop monitoring leads to better real-time detection, which helped Canadian prairie farmers increase their wheat production by 15% (Al-Mallahi, 2024) and Kenyan small-scale farmers map maize fields at a reasonable cost (Wanyama *et al.,* 2021). The Dutch track water use by blockchain technology, while edge computing reduces response time at remote agricultural locations in Central Asia. Technology developments in South Korea advance 5G for quick irrigation control (Watts *et al.,* 2019). The Netherlands, along with the U.S., participates in blockchain and edge computing for data processing efficiency and security (Ahmed *et al.,* 2024). Smart irrigation technology is moving toward worldwide adoption due to recent innovative developments.

5.2 Research Directions

Scientists will tackle existing issues in research by building upon these emerging trends. The implementation of solar-powered IoT systems with renewable energy systems stands as a primary research priority because they helped Spanish olive farms conserve 40 percent of their energy costs and Ethiopian smallholder farmers received an additional 50 percent irrigation capacity (Mérida García, 2020; Tesfaye *et al.,* 2021). Solar IoT implementations in Sub-Saharan Africa help to decrease the carbon emissions of these systems (Mukisa *et al.,* 2022). Research teams in Bangladesh are developing affordable AI-Internet of Things kits that aim to give small farmers the power they need (Satapathy *et al.,* 2022), and AI software from Brazil predicts drought timing patterns compatible with Southern Africa (Chivangulula *et al.,* 2024). Through collaboration between agronomists and data scientists in Japan and Canada, researchers have found comprehensive answers (Suresh *et al.,* 2024). The established directions work to establish both sustainability and access to smart irrigation throughout agricultural locations with varied environments.

5.3 Policy and Industry Implications

The complete implementation of these innovations depends on strong support from both government policies and industrial organizations. Governments should provide financial support for solar-IoT systems. The German public-private partnerships build farmer-friendly platforms that serve as a model for European territories (Sjaf *et al.,* 2022). The adoption rate of drones and blockchain in industries continues to grow because Mexico established farmer training programs for UAV operation and IEEE developed universal IoT standards for Southeast Asia (Tiwari *et al.,* 2021; Wangere, 2024). International joint investments in AI and renewable energy research development are speeding up deployment worldwide through Chinese edge-blockchain pilot programs (Yang *et al.,* 2025). These initiatives guarantee that technology breakthroughs become practical benefits that reach all farmers justly across the board.

6. Discussion

6.1 Synthesis of Findings

Smart irrigation has experienced a revolutionary change because of AI and IoT implementation that has been proven through multiple case studies and research developments. Through the combination of IoT sensors with AI analytics systems and precision irrigation methods, water savings reached between 20-35% in Australian, Indian, and Spanish locations (Wei *et al.,* 2024) while drone-based farming and predictive analysis techniques improved agricultural productivity in North American and African territories (Guebsi & El Wai 2025). Several roadblocks, mainly stemming from technical difficulties regarding rural African internet connectivity combined with economic factors influencing Asian smallholders and European privacy rights, are preventing the widespread adoption of the proposals. The integration of solar-powered systems in Ethiopia, combined with blockchain solutions in the Netherlands, provides a solution for existing barriers, but China faces difficulties in achieving standardization following their deployment (Abiri *et al.,* 2023; Polymeni *et al.,* 2024). This work highlights two conflicting trends that show major potential restricted by continuing obstacles that affect different regions and resource amounts.

6.2 Implications for Stakeholders

The results deliver significant ramifications that affect stakeholders all over the world. The implementation of AI-IoT technology provides efficiency improvements to farmers yet necessitates affordable user-friendly solutions, which are vital for South Asian and Latin American small-scale farmers (Muhammed *et al.,* 2024). Water-scarce nations such as Morocco need policymakers to establish both training programs and financial aid schemes, which have proven successful in Israel (Tinazzi, 2024). The refinement of scalable and energy-efficient technologies requires research collaboration across different fields of study similar to Canadian research institutions (Neethirajan, 2024). The adoption of new agricultural technologies, such as edge computing in remote Central Asian regions, can be achieved through industry collaborations led by drone manufacturers and IoT developers, much like in Germany and by extending to Central Asian farms. The stakeholders must work together toward producing effective transformational outcomes from research through efforts that suit different agricultural settings.

6.3 Limitations of the Review

The review aims to be comprehensive; however, some restrictions need to be acknowledged. The majority of studies in English-language publications bias researchers against evaluating important research conducted in Spanish or Chinese, which could hide valuable innovations from Latin America and East Asia. The examination of recent research during the last decade fails to include fundamental studies that established the framework for smart irrigation development. Successful case studies dominate the research due to published limitations since resource-limited areas, particularly Sub-Saharan Africa, often fail to report their unsuccessful implementations (Higginbottom et al., 2021). Further research should expand linguistic and geographical bounds in reviews to achieve full global representation of research.

Conclusion

Artificial Intelligence (AI) integration with the Internet of Things (IoT) brings substantial opportunities for global water shortage management and increased agricultural crop outputs. Predictive AI models and IoT monitoring, along with drone application, blockchain technology, and solar-powered systems, prove effective in water utilization optimization and increased yield production throughout Australia to Ethiopia. The extensive implementation faces multiple obstacles that include technical obstacles as well as financial hurdles and scalability problems and ethical issues which predominantly impact regions such as Sub-Saharan Africa and South Asia which have limited resources. The implementation of edge computing with 5G technology and renewable energy integration requires major combined work to achieve their future applications.

Technology in precision agriculture earns its value because it generates sustainable farming systems through precise management capabilities. Implementing these methodologies demands the elimination of the digital gap through affordable technology systems that support robust policies across the board. The authors propose that researchers should conduct more studies about energy-efficient, affordable agricultural system designs while improving collaborative work between agronomists and engineers along with policymakers. People across the world in agricultural roles alongside governmental organizations, scientific researchers, and industrial experts should join forces to lead this technology adoption. AI and IoT-based smart irrigation represent a vital opportunity in the present climate to protect both our food supply and environmental systems because water availability continues to decrease.

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Characterization of Dried Orange Waste as a Valuable Ingredient in Broiler Chicken Diets

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Abstract

Several valorization strategies have been explored as alternatives to mitigate the disposal of orange waste in landfills. In the orange juice industry, over 50% of the raw material is converted into by-products that are rich in bioactive compounds and possess high nutritional value. Enhancing the utilization of these by-products could serve as a crucial strategy for advancing a circular economy. Orange waste represents a potential source of revenue or cost savings for juice production facilities, given its potential as a source of value-added products and energy vectors. To produce a flour from orange juice by-product and characterize it, in order to incorporate it in broiler chicken feed. The sun-dried and grounded (particle size < 1mm) orange by-products were characterized in terms of its chemical composition, dietary cellulose, phenolic compounds, and antioxidant potential. Dried orange pulp presented a moderate high content of dietary cellulose (89.19% dry matter (DM)), minerals (ash = 3.81% DM), and total phenolic compounds (202.59 mg gallic acid equivalent (GAE)/100 g of DM). In general, orange by-products showed total cellulose content, flavonoids content, and antioxidant activity with the following values, 22.03 %, 430.70 mg QE/100g, and 1158.8 FRAP mg/g FRAP mg/g, respectively. The qualification of phenolics compounds in dried orange pulp demonstrated that flavonones were the most presents with a high content of hesperidin 61.29 mg/g of orange juice powder by-product. Furthermore, the most elevated concentration in hydro cinnamic acids content was the ferulic acid with (27.1 mg/g). These findings make dried orange pulp a valuable product for broiler chicken, contributing not only to animal welfare but also to more cost-effective and eco-friendly poultry production practices.

Keywords: *Orange waste, Hydro cinnamic acids, Hesperidin, Ferulic acid.*

Introduction

Fruits and vegetables have the highest waste rates of any food, i.e., 45% (Caldeira et al., 2019). Citrus is one of the most important fruit crops in the world with an annual production exceeding 122.5 million tons and one-third of the crop is processed (Jiang et al., 2014). Peel (flavedo) and rag (albedo) by-products are generated from the production of citrus juice, and represent about 45%–60% of the fruit (Berk et al., 2016). These by-products contain nutrients and bioactive compounds; they are considered a problem. Therefore, the need for more sustainable practices, with reduced environmental impacts towards the application of a circular economy in the food system, represents a key strategy for the future. Fruit is widely known for its functional potential and, more recently, fruit by-products have gained attention due to their higher nutritional contents in comparison to their respective edible portion (Can-Cauich et al., 2017). It is noteworthy that the use of by-products also contributes to reduce the economic and environmental problems caused by the discard of waste by fruit processing industries (O'Shea et al., 2012).

Valorizing co-products offers both environmental and economic benefits for the food sector, contributing to the development of sustainable value chains in agriculture and processing. There is currently high demand for transforming co-products into new ingredients through sustainable processes. This involves reducing disposal costs and improving environmental impact by transforming these co-products into useful products for various industries such as food, dietary, pharmaceutical, cosmetic, and others. As previously detailed, orange juice by-product is mostly destined for animal feed (Bampidis et al., 2006), or for essential oils (Sahraoui et al., 2011). For this, an adequate process for developing the by-product and its complete characterization, in terms of composition, and also in relation to functional properties, is necessary before its application in real and easily manufactured animal feed, which are the objectives of this study.

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Materials and Methods

Preparation and obtaining the powdered orange juice co-product

The orange juice waste, obtained from an Algerian processing company in January 2021, was transported to the Biotechnology Laboratory at the Higher School of Agronomy in Mostaganem, Algeria. It was dried in a glass greenhouse for four days, then ground into a fine powder with particle size <1 mm for easier incorporation into broiler chicken feed (Readh et al., 2023).

Proximate composition analysis

Determination of dry matter

The sample is dehydrated in an oven at 105°C for 24 hours (Özcan et al., 2021; Ebouel et al., 2023).
The dry matter of the samples are calculated by the following expression :

DM (%) = Mass (DM)(g)/Mass (sample) (g) × 100 (1)

Determination of Ash

The dehydrated samples will be heated to 550°C for 3 hours in a muffle furnace until white ashes are obtained. The specimens are weighed for the calculation and expression of results (Lagha-Benamrouche et al., 2018; Ebouel et al., 2023). The following formula (equation 3) were utilized to calculate the mineral matter content (MM):

Mineral Matter (MM %) = (M2 - M0) / (M1 - M2) × 10 (3)

M0: Mass of the empty crucible (in grams)
M1: Mass of the crucible containing the test sample (in grams)
M2: Mass of the crucible and the raw minerals (in grams)
The content of MM is expressed in g/100g of the sample.

Proteins

The aliquot is ground with 25ml of physiological saline solution on ice and the mixture is filtered using filter paper. From this filtrate, 1ml is taken and added to 100 ml of distilled water. Then, from this mixture, 1ml is transferred into a test tube, and Lowry reagent is added and allowed to stand for 10 minutes. Afterward, half-diluted *Folin-Ciocalteau* reagent is added to each tube. The tubes are then agitated using an electric homogenizer for 2 minutes and left to stand for 30 minutes at 4°C in the dark. The readings are taken with a spectrophotometer at a wavelength of 700nm. The optical densities obtained are converted into protein percentages using a calibration curve prepared under the same conditions (Satpathy et al., 2020).

Orange By-Product Extraction

The solvent for the production of the extracts utilized was the absolute methanol. Briefly, 20 g of sample 200 mL of absolute methanol was added, the mixture was agitated on a compact shaker (Edmund Bühler GmbH model KS-15, Hechingen, Germany) at 450 rpm for 24 h at room temperature (23 ± 1 °C), protected from the light. After that, the extrait sample was stored to an amber pear-shaped flask. To evaluate the antioxidant capacities of the dried orange pulp extract, free radical DPPH inhibition and ABTS assays were performed. In addition, the Total Phenolic Compounds (TPC), the Total Flavonoid Content (TFC) and condensed tannins were determined.

The quantification of phenolic compounds

Total phenolic content

The polyphenols were quantified using spectrophotometry following the method described by (Jaradat et al., 2015). One milliliter of the methanolic extract (20 g of powder in 200 mL of methanol-water (8v/2v)) was mixed with 5 mL of *Folin-Ciocalteu* reagent. This solution was diluted tenfold and 4 mL of 75 g/L Na2CO3 was added. A standard curve was prepared using a 1 g/L gallic acid solution with dilutions of 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 µg/mL. Absorbance was measured at 765 nm after a 1-hour incubation at room temperature. The color intensity is proportional to the level of oxidized phenolic compounds capable of reducing *Folin-Ciocalteu* reagent. The results are expressed as milligrams of gallic acid equivalent per gram of dry extract.

Flavonoids

The flavonoids in dried orange pulp were quantified using spectrophotometry according to the method described by (Pertiwi et al., 2020). A volume of 0.75 mL of AlCl3·6H2O (2%) was mixed with an equal volume of the extract. After a 10-minute incubation, the optical densities were read at 430 nm in the UV-Visible range. Flavonoid concentrations were determined against a standard curve generated using quercetin (0_60 mg/L). The results are expressed as milligrams of quercetin equivalent (EQ) per gram of dry extract.

Condensed Tannins

According to Agbo et al. (2015), the modified vanillin assay was used to determine the total tannin content. For this purpose, 1.5 ml of concentrated sulfuric acid was combined with three milliliters of a 4% vanillin solution in methanol, which was then added to 50 ml of a diluted sample. The absorbance relative to methanol as a blank was measured at 500 nm, and the mixture was left to stand for 15 minutes. A calibration curve with catechin was used to express the total amount of condensed tannins in milligrams of catechin equivalent per 100 grams of dry matter (mg CE/100g DM). The calibration curve ranged from 0 to 400 µg/ml (R^2 = 0.999).

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Antioxidant Activity

Free Radical DPPH Inhibition Assay

For the free radical DPPH inhibition assay, the method described by (Gargouri et al., 2013) and modified by (Mohammedi et al., 2023), was applied. Briefly, a volume of 0.1 mL of each extract was transferred into a test tube. The reaction was carried out for 30 min in the dark. Then, absorbance was measured at 517 nm. An aliquot of 2 mL of DPPH (2,2-diphenyl-1-picrylhydrazyl) solution (0.4%) in ethanol and 0.1 mL of phenolic extract at different concentrations ranging from 31.25 µg/mL to 500 µg/mL was mixed and shaken vigorously. After 30-min incubation at 30°C in the dark, the absorbance was measured at 517 nm against a blank sample. A control assay was performed with the solvent in which the sample was dissolved. The inhibition percentage (IP) of DPPH was calculated according to the following equation (5):

$$\textbf{IP (\%)} = (Ac - As)/Ac \times 100 \quad (5)$$

Where:

(Ac) is the absorbance of the control and **(As)** is the absorbance of the sample.

ABTS radical scavenging activity

As reported by Gargouri et al. (2013), a modified approach was employed by (Mohammedi et al., 2023), to assess ABTS radical scavenging activity. The ABTS radical cation was generated by combining an aqueous solution of ABTS (7 mM) with potassium persulfate (2.45 mM, final concentration) and incubating it in darkness at 25°C for 12–16 hours. The resulting solution was diluted with ethanol to attain an absorbance of 0.70 (± 0.02) at 734 nm. Subsequently, 20 µl of trolox or the test sample in water were introduced into 2.0 mL of this diluted solution, and absorbance readings were taken at 734 nm at 30 °C following 6 minutes of initial mixing. Blank samples for each assay were prepared using appropriate solvents. The antioxidant's efficacy was evaluated by measuring its capacity to reduce the concentration of the ABTS radical cation, with results expressed relative to the trolox antioxidant equivalent concentration. This assessment of antioxidant activity was conducted at three distinct concentrations.

Quantification of the Polyphenolic Compounds by HPLC-DAD/UV

Phenolic compounds were identified using high-performance liquid chromatography (HPLC). This characterization was performed by comparing the retention times of the chromatographic peaks of the sample, in accordance with the methodology specified by Maalej et al. (2022). The concentration of phenolic compounds present in the ethyl acetate extracts was quantified using an HPLC-DAD system (1260-Agilent, Germany). An Eclipse DB C18 column, with a particle size of 5 µm and dimensions of 4.6 x 25.0 mm, was used for compound separation in this study. Two distinct mobile phases were used for this purpose: solvent A, consisting of a 0.1% acetic acid aqueous solution, and solvent B, composed of 100% acetonitrile. The separation was carried out following an acetonitrile gradient with the following conditions: from 0 to 22 minutes (10 % B) and from 22 to 32 minutes (50 % B). The conditions were then modified as follows: (100 % B) from 32 to 40 minutes, (100 % B) from 40 to 44 minutes, and (10 % acetonitrile) from 44 to 50 minutes. The total analysis cycle duration was 50 minutes. Samples were injected at a flow rate of 0.5 ml/min, with an injection volume of 5 µl, maintained at a temperature of 40°C. The ultraviolet-visible (UV_VIS) spectra of the phenols were recorded over a range of 190 to 400 nm, and the samples were detected at wavelengths of 254, 280, and 330 nm, according to the protocol described by Mohamadi et al. (2023).

Statistical Analysis

The characterization of orange pulp was conducted using five replicates. Data were analyzed using appropriate statistical methods to assess variability and ensure reliability. Descriptive statistics were computed, and results are expressed as mean.

Results

Biochemical Composition of Dried Orange Pulp

The chemical composition of the orange juice by-products is presented in Table 1.

Total Content of Polyphenols and Flavonoids

The quantified levels of polyphenols, flavonoids, tannins, and the measured antioxidant activities (DPPH and FRAP) are presented in Table 2.

Table 1. Chemical composition of dried orange by-products obtained from the orange juice extraction ($g.100g^{-1}DM$)

Parameter	Dried Orange Pulp (DOP)
Dry Matter	89.19
Ash	3.81
Crude Proteins	5.50

Each value is the mean of (n=5). The results are expressed as means ± standard deviations

Table 2. Phenolic Compounds and Antioxidant Activity of the studied by-products (*Citrus Siensis*)

Parameter	Dried Orange Pulp (DOP)
Phenolic compounds mg GAE/g	202.59
Flavonoids mg QE/g	430.70
Tannins mg CE/g	150.00
FRAP mg/g	1158.8
DPPH mg/g	270.68

Each value is the mean of (n=5). The results are expressed as means ± standard deviations

The analysis of dried orange pulp revealed that it contained significant quantities of bioactive compounds, contributing to its antioxidant potential. The phenolic compounds and flavonoids present in DOP reflect its high nutritional value and potential health benefits. Additionally, the notable levels of tannins further indicated its bioactive richness. The antioxidant capacity, as measured by FRAP and DPPH values, confirmed the strong antioxidant properties of DOP.

High-Performance Liquid Chromatography with Diode Array Detection (HPLC-DAD) Polyphenolic Profile of Orange Pulp

The phenolic profile and polyphenol content of orange by-products were analyzed using HPLC-DAD, enabling routine screening and quantification of polyphenols.

The study identified 19 phenolic compounds, including four flavonoids, across three groups: phenolic acids, flavanone glycosides, and flavanol glycosides (Table 3).

Table 3. Phenolic Compounds in Orange Pulp

	RT	Component	mg/g	Λ nm	Subclasses of Compounds
1	8.92	Caffeic acid	1.00	330	Hydrocinnamic acids
2	17.12	Ferulic acid	27.1	280	
3	19.83	p-Coumaric acid	0.3	280	
4	7.03	p-Hydroxybenzoic acid	1.31	254	Hydrobenzoic acids
5	14.45	Vanillic acid	0.1	254	
6	23.86	Dydimine	0.61	330	Flavonones
7	20.91	Naringenin	0.2	280	
8	23.09	Naritunine	1.76	280	
9	32.77	Hesperidin	61.29	330	
10	42.72	Hesperetin	0.3	280	
11	22.74	Luteolin	0.8	330	Flavones
12	25.96	Apigenin	0.8	254	
13	15.15	Rutin	0.4	330	Flavanols
14	22.92	Quercetin	10.6	254	
15	13.66	Epicatechin	7	280	
16	22.51	Quercitrin	4.2	254	
17	10.40	Protocatechuic acid	Trace	280	Phenolic acids
18	7.89	Chlorogenic acid	2.7	254	
19	4.48	Ascorbic acid	3.2	280	
T			123.67		

RT: retention time; C: concentration (mg/mL); λ nm: wavelength; T: Total

Each compound was characterized by its retention time (Rt), maximum absorption wavelengths (λmax), structural class, and main MS/MS fragments. The most abundant compound is hesperidin, a flavonone, which stands out with a concentration of 61.29 mg/g. This dominance is followed by ferulic acid, a hydro cinnamic acid, at 27.1 mg/g, highlighting the significant presence of phenolic acids. Additionally, quercetin, rutin, and epicatechin, belonging to the flavanols, contribute substantially to the overall antioxidant capacity of the orange pulp. The variety of compounds, including both flavonoids and phenolic acids, suggests a strong potential for antioxidant activity, further underlining the nutritional value and functional properties of the pulp.

Discussion

The orange pulp used in our study showed higher levels of dry matter and proteins compared to those reported by El-Beltagi et al. (2022). It also exhibited significantly elevated ash content, surpassing Castro et al. (2020), while

maintaining a similar protein content. The dry matter content of our oven-dried orange peel powder was closely similar to Özcan et al. (2021) result. However, our results differ from García-Rodríguez et al. (2019), who reported a broad protein range in orange pulp by-products, from 7.3 g/kg dry matter in clementines to 110 g/kg in orange pulp. Additionally, Pourhossein et al. (2019) highlighted compositional differences between our orange pulp and the orange peel in their study, which had 88.00% dry matter, 5.46% protein, 1.10% calcium, 0.05% phosphorus, and 7.00% ash. In contrast, Akpe et al. (2019) found biodegraded sweet orange peel containing 7.18% crude protein and 7.50% ash.

Phenolic compounds in citrus peels have been reported in the range of 131.0 to 223.2 mg of gallic acid equivalent (GAE) per 100 g (Ghasemi and Ebrahimzadeh, 2009). The orange pulp used in our investigation exhibited a higher total phenolic content compared to the results reported by Al-Juhaimi et al. (2014). In their study, they extracted phenolic compounds from orange peel, obtaining 178.90 mg GAE/100 g, and from mandarin peel, yielding 169.54 mg GAE/100 g.

Furthermore, their analysis revealed phenolic concentrations in orange pulp of 123.02 and 104.98 mg GAE/100 g, respectively. Our findings revealed lower levels of phenolic compounds compared to the content reported in the study conducted by (Castro et al., 2020), with a content of 534 mg gallic acid equivalent (GAE)/100 g dry matter. Furthermore, our experiment revealed that the average flavonoid content of the orange pulp showed moderate similarity to the findings of Abou-Arab et al. (2016).

Specifically, the microwave-dried orange pulp exhibited flavonoid variations ranging from 437.50 mg quercetin equivalent (QE)/100 g in mandarins to 453.33 mg QE/100 g in *C. Valencia* and *C. Balady* oranges. Additionally, the flavonoid concentrations in oven-dried orange peels varied from 150.83 mg QE/100 g in *Citrus Balady* oranges to 327.50 mg QE/100 g in *Citrus Valencia* oranges.

In contrast, the study by Lagha-Benamrouche and Madani (2013) in Algeria found that the peels of six orange varieties had lower flavonoid concentrations than those observed in our investigation. The total flavonoid content in sweet orange peel varies with drying and grinding methods (Garau et al., 2007). Fresh orange peel initially contained 506.82 mg QE/g, decreasing to 309.9 mg QE/g after microwave drying and to 365.40 mg QE/g after oven drying (Abd-El Ghfar et al., 2016). The correlations between antioxidant activity (ABTS and DPPH) and phenolic compounds align with Barreca et al. (2014) and Papoutsis et al. (2016). Additionally, Abd-El Ghfar et al. (2016) found higher flavonoid content in oven-dried lemon peel than in microwave-dried peel. Our study's orange pulp flavonoid content exceeded that of oven-dried orange peels reported by Abou-Arab et al. (2016).

The dehydrated orange pulp in our study showed higher levels of caffeic, ferulic, and hydrobenzoic acids compared to kinnow peel (Rafig et al., 2019) but lower levels of quercetin, caffeic acid, naringin, and rutin than those reported by Omoba et al. (2015). Additionally, hydroxycinnamic acids like caffeic, ferulic, and p-coumaric acids were also detected, confirming findings by De Ancos et al. (2017), Cheong et al. (2012), and Ferreira et al. (2018) in orange pulp, methanolic extracts of *Citrus microcarpa* bark, and extracts from mandarin peels.

The presence of naringenin, hesperidin, narirutin, and didymin in the orange pulp aligns with De Ancos et al. (2017), with didymin unique to orange by-products, whereas narirutin and hesperidin were detected in citrus by-products derived from both oranges and lemons (Gómez-Mejía et al., 2019). Moreover, the hesperidin concentration in the analyzed orange pulp exceeded that found in two orange peel varieties, recorded at 26.81 mg/g and 20.99 mg/g, as reported by Chen et al. (2017). This hesperidin level was comparable to those in lemon peels after methanol extraction (Huang and Ho, 2010). Additionally, our findings align with hesperidin and naringin levels in C. reticulata peel (50.13–100.52 mg/g) (Liu et al., 2013). Low luteolin levels (0.08–0.21 mg/g) matched those identified by Wang et al. (2008), and the presence of rutin, quercitrin, quercetin, and epicatechin aligns with Molina-Calle et al. (2015). The examined orange pulp showed higher levels of rutin and quercetin than those found in the peels of eight citrus fruits (Wang et al., 2008). Our analysis focused on flavanone glycosides, revealing that hesperidin was the predominant compound, surpassing levels reported by Molina-Calle et al. (2015). Additionally, hesperidin and naringenin content in our study was higher than those found by De Ancos et al. (2017) in various orange pulps and juices (49-434 µg/g).

Conclusion

The chemical composition of orange waste supports various applications, with methanol and acetic acid yielding higher bioactive compound extraction than other solvents. High phenolic content and glucose adsorption capacity make it a potent source of natural antioxidants, particularly hesperidin, for food additives, enhancing shelf life and developing functional foods within a circular economy.

Declarations

Author Contribution Statement

A.R.C.E.: Data collection, investigation, formal analysis, methodology and writing the original draft
M.L.: Project administration, supervision, methodology, review and editing
K.B.: Project administration, supervision, methodology, review and editing

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Conflict of Interest
The authors declare no conflict of interest.

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Optimizing Okra (*Abelmoschus esculentus*) Productivity through Integrated Nutrient Management: Effects of NPK Fertilizer and Cow Dung Manure in the Sudan Savanna, Nigeria

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Abstract

This study evaluated the influence of NPK fertilizer and cow dung manure (CDM) on okra (*Abelmoschus esculentus*) yield and its components under the Sudan Savanna conditions of Nigeria. A 4 × 4 factorial experiment in a randomized complete block design with four replications was conducted at Teaching and Research farm, Bayero University, Kano. Treatments included four levels each of NPK fertilizer (0, 200, 300, and 400 kg ha^{-1}) and CDM (0, 2.5, 5.0, and 7.5 t ha^{-1}). Results indicated that NPK and CDM significantly ($P < 0.001$) influenced pod yield, with the highest yields obtained at 200 kg ha^{-1} NPK and 7.5 t ha^{-1} CDM (4367.00 kg ha^{-1} in 2019 and 9148.00 kg ha^{-1} in 2020), representing a 391% and 384% increase, respectively, over the control (888.00 kg ha^{-1} in 2019 and 1889.00 kg ha^{-1} in 2020). Pod length increased significantly ($P < 0.001$) with 100–200 kg ha^{-1} NPK in 2019 but was not significantly affected in 2020, suggesting seasonal variability. CDM at 7.5 t ha^{-1} produced the highest pod count (18.47 in 2019 and 24.73 in 2020), outperforming lower rates. The findings underscore the benefits of integrated nutrient management, as the combination of NPK and CDM enhanced soil fertility, increased pod number, and improved total yield. These results confirm that organic and inorganic fertilizers complement each other in optimizing okra productivity. Thus, integrated nutrient management using 200 kg ha^{-1} NPK and 7.5 t ha^{-1} CDM could be adopted by the farmers for sustainable okra production in nutrient-deficient soils of the Sudan Savanna region.

Keywords: *Fertilization strategy, okra, yield optimization, soil fertility, Sudan savanna*

Introductıon

Okra (*Abelmoschus esculentus* L. Moench) is an economically important vegetable crop widely cultivated in tropical and subtropical regions, including Nigeria. It is rich in vitamins, minerals, and antioxidants, making it an essential part of human nutrition (Ibitoye and Kolawole, 2022). However, the yield of okra in the Sudan Savanna ecology of Nigeria remains low due to poor soil fertility and inadequate nutrient management practices (Hamisu *et al.,* 2021). Integrated Nutrient Management (INM), incorporating the principles of Integrated Soil Fertility Management (ISFM), is a sustainable approach to enhancing soil health, crop productivity, and long-term agricultural viability (Pathan *et al.,* 2024). By combining organic and inorganic fertilizers, this approach optimizes nutrient availability, where organic amendments improve soil structure and microbial activity, while inorganic fertilizers provide essential nutrients for plant growth (Liu *et al.,* 2024). Additionally, Justus von Liebig's law of the minimum states that plant growth is limited by the most deficient nutrient, reinforcing the need for balanced fertilization to maximize okra yield (Bimpe *et al.,* 2023).

Despite the importance of okra in Nigeria, its yield remains suboptimal due to nutrient depletion, poor soil fertility, and over-reliance on synthetic fertilizers (Badu Brempong and Addo-Danso, 2022). Conventional fertilization methods often lead to soil degradation, nutrient imbalances, and declining crop productivity (Akter *et al*., 2020; Ayodele *et al*., 2020). Additionally, excessive use of inorganic fertilizers contributes to environmental pollution and increased production costs (Abdalla *et al*., 2024). The limited adoption of integrated nutrient management strategies in the Sudan Savanna region exacerbates the problem, necessitating research on the most effective nutrient management approach to enhance okra yield while maintaining soil health.

Previous studies indicate that INM enhances soil structure, microbial activity, and nutrient availability, leading to higher crop productivity (Yusuf *et al*., 2020; Gupta *et al.,* 2022). However, in the Sudan Savanna region, erratic rainfall, high temperatures, and nutrient-deficient soils pose significant challenges to crop production (Olowolafe and Dibal, 2019), highlighting the need to assess INM's impact on okra yield and its components to optimize nutrient management for sustainable agriculture in Nigeria. This study aims to evaluate the impact of different rates of NPK fertilizer and CDM on the yield and yield components of okra under Sudan Savanna conditions.

Materials And Methods

The trials were conducted at the Teaching and Research Farm of Bayero University, Kano (Latitude 11° 58.861'N and Longitude 08° 31.177'E, with altitude of 476m above sea level). The experimental field was properly cleared of debris ad stumps. The land was then ploughed, harrowed to fine tilt and ridged. The field was demarcated into three replicates consisting of sixteen plots of gross plot size of 3 m x 3 m (9 m^2) and a net plot of 3 m x 1.5 m (4.5 m^2) which consists of the two inner rows. A pathway of 0.5 m and 1.0 m was between plots and replication was maintained to provide ease of movement and prevent nutrient drift. The experiment was a 4 x 4 factorial combination laid out in a randomized complete block design with four replications. The treatments comprised of varied rates of NPK fertilizer (0, 200, 300, and 400 kg ha^{-1}) and cow dung manure (CDM) (0, 2.5, 5.0, and 7.5 t ha^{-1}), resulting in 16 treatment combinations.

The okra seeds variety NHB-AI-13 was sourced from the National Horticultural Research (NIHORT) substation, Bagauda, Kano state. The cow dung was sourced from the livestock unit of the department of Animal Science of Bayero University Kano while the NPK fertilizer was from the department of Agronomy, BUK. The cow dung manure was applied as a basal application by broadcasting and incorporating it into the soil two weeks prior to sowing for ease of decomposition and to allow CO_2 escape, thus preventing scorching of the tender okra seedlings. NPK fertilizer (15-15-15) was applied according to the designated rates at 2 WAS about 10 cm radius away from the plant stand using ring method. For the treatments without CDM and NPK, no manure was applied throughout the growing season.

Three to four seed s of okra (NBH-AI-13) were sown directly into the soil at a depth of 2 cm with a spacing of 30 cm x 30 cm. the seedlings were later thinned to one plant per stand at 2 WAS. The crops were managed using standard agronomic practices for okra cultivation, including weeding, and pest control. Weeding was done manually as at when due using hoe. The defoliating insect pest were managed using Lampda (Cyhalothrin 2.5 EC) a contact insecticide applied at 2 L ha^{-1} using Cp3 knapsack sprayer set at a pressure of 2.1 kg m^{-2}.

Data were collected using standard agronomic procedure on the following yield component and yield of okra: Number of pods per plant, Individual pod weight, pod length, pod diameter and total pod yield (kg ha^{-1}). All data collected was subjected to analysis of variance (ANOVA) using SAS (Version 9.1) and significant means were separated using Duncan Multiple Range Test (DMRT) at 5% probability level.

Results And Dıscussıon

Effects of NPK Fertilizers and Cow dung manure on pods count per plant and pod weight per plant

Table 1 presents the effect of NPK fertilizer and cow dung manure (CDM) on the pods count per plant and individual pod weight of okra during the 2019 and 2020 wet seasons. The results show that while both inputs significantly ($P < 0.001$) influenced pod number, they had no significant ($P > 0.05$) effect on individual pod weight. Higher pods count were recorded with NPK application (100-300 kg ha^{-1}), whereas the control resulted in the lowest values across both seasons. Similarly, CDM at 7.5 t ha^{-1} produced the highest pod count, followed by 5.0 t ha^{-1}, outperforming lower rates in both years. The effectiveness of high-rate NPK in enhancing pods count highlights its role in promoting reproductive growth, while CDM's success at 7.5 t ha^{-1} suggests that organic fertilization is a viable alternative to synthetic fertilizers for increasing okra yield. This underscores the importance of balanced nutrient management, particularly in nutrient-deficient soils. These findings align with Muhammad and Sanda (2019), who reported that applying 800 kg ha^{-1} of NPK or a 50:50 combination of NPK and poultry manure significantly increased the number of pods per plant and overall yield. Similarly, Adekiya *et al*. (2020) found that poultry manure application improved okra pod production in comparison to sole NPK fertilizer.

The interaction between NPK and CDM on the pods count per plant was significant across both seasons, as shown in Table 2. The combined application of 200 kg ha^{-1} NPK and 7.5 t ha^{-1} CDM produced the highest pods count per plant in 2019 (18.47) and 2020 (24.73), outperforming other treatment combinations. This suggests that integrating organic and inorganic fertilizers creates a more balanced nutrient supply, enhancing pod formation and overall productivity. These findings align with those of Meena (2024), who reported that combining organic and inorganic fertilizers improved fruit set and pod production in okra. Similarly, Karim *et al.* (2024) found that integrating mineral fertilizers with organic amendments significantly enhanced crop yield by improving soil nutrient availability and plant growth. These results reinforce the benefits of integrated nutrient management in optimizing okra production through improved soil fertility and plant performance.

Effects of NPK Fertilizers and Cow dung manure on Pod length, Pod diameter, and Total pod yield per hectare.

The effects of NPK and CDM rates on pod length, pod diameter, and total pod yield of okra in the 2019 and 2020 seasons are presented in Table 3. Results show that applying 100 and 200 kg/ha NPK significantly ($P < 0.001$) increased pod length in 2019 but had no significant ($P > 0.05$) effect in 2020, suggesting seasonal variability in nutrient response. Similarly, pod diameter was not significantly affected in either season, indicating that factors such as genetics, soil conditions, and environmental variables may play a more dominant role than nutrient application alone. However, the significant increase in total pod yield (3011.14 & 3011.14 kg ha^{-1}) with 200 kg ha^{-1} NPK application across both seasons highlights the importance of adequate nutrient supply in enhancing

productivity. This suggests that while pod size may not be directly influenced, optimizing NPK application can significantly boost total yield, making it essential for maximizing okra production. These findings align with Esmond *et al*. (2023), who reported a significant increase in okra pod weight and yield with higher NPK rates, while Sabo and Zubairu (2021) and Sababa *et al.* (2024), who found that optimal NPK and NPS fertilizer rates improved pod length and yield, reinforcing the role of proper nutrient management in enhancing okra productivity, respectively.

Table 1: Effect of NPK and Cow dung manure on pods count per plant and pod weight per plant of Okra at BUK during 2019 and 2020 wet season

Treatment	Pods count Plant-^{1} (#)		Individual Pod weight (g)	
	2019	2020	2019	2020
NPK (kg ha^{-1})				
0	9.65^{b}	12.82^{c}	22.86	39.25
100	11.36^{a}	15.23^{ab}	26.10	39.91
200	12.53^{a}	16.23^{a}	24.25	43.91
300	11.87^{a}	14.73^{b}	26.18	44.16
LS	**	**	NS	NS
SE±	0.46	0.43	2.45	1.89
Cowdung Manure (t ha^{-1}) [CDM]				
0	9.38^{c}	11.86^{c}	20.01	41.42
2.5	9.83^{c}	12.98^{bc}	26.60	42.83
5.0	11.21^{b}	14.23^{h}	25..04	41.75
7.5	15.00^{a}	19.94^{a}	27.75	41.25
LS	*	**	NS	NS
SE±	0.46	0.43	2.45	1.89
Interaction				
NPK x CDM	**	**	NS	NS

Means followed by the same letter(s) are not significantly different at 5% level of probability according to DMR Test. LS=Level of significance; **and *=Significant at 1and 5%; NS=Not significant

Table 2: Interaction of NPK and Cow dung manure on Pods count per plant of Okra during 2019 and 2020 wet season

Treatment	Cow dung Manure (t ha^{-1})			
	0	2.5	5.0	7.5
NPK (kg ha^{-1})		2019		
0	6.97^{no}	7.13^{j-o}	11.40^{c-g}	13.10^{bcd}
100	12.10^{b-e}	8.43^{i-o}	10.87^{d-i}	13.97^{bc}
200	10.07^{e-m}	11.13^{d-h}	10.47^{d-k}	18.47^{a}
300	10.10^{e-l}	10.80^{d-j}	12.10^{b-f}	14.47^{b}
LS		**		
SE±		0.92		
		2020		
0	8.93^{im}	13.13^{fgh}	12.73^{f-i}	16.47^{c}
100	13.50^{f}	13.37^{fg}	12.67^{f-j}	21.40^{b}
200	11.67^{f-k}	12.67^{f-j}	16.40^{cd}	24.73^{a}
300	13.33^{fg}	12.73^{f-i}	15.10^{de}	17.73^{c}
LS		**		
SE±		0.87		

Means followed by same letter(s) are not significantly different at 5% level of probability according to SNK Test.

Table 3: Effect of NPK and Cow dung manure on Pod length, Pod diameter and Total pod yield of Okra at Bauchi during 2019 and 2020 wet season

Treatment	Pod length (cm)		Pod diameter (cm)		Total pod yield (Kg ha^{-1})	
	2019	2020	2019	2020	2019	2020
NPK (kg ha^{-1})						
0	7.31^{b}	8.21	10.40	10.99	1715.10^{d}	2490.00^{c}
100	7.99^{a}	8.39	10.69	11.26	2348.21^{c}	4463.25^{b}
200	7.65^{a}	8.43	10.34	11.16	3011.14^{a}	5366.83^{a}
300	7.51^{b}	8.58	10.34	11.23	2678.10^{b}	4712.42^{b}
LS	**	NS	0.16	0.17	**	**
SE±	0.12	0.14	NS	NS	81.38	131.09
Cow dung Manure [CDM] (t ha^{-1})						
0	7.75	8.12	10.59	10.58^{b}	1690.20^{c}	2671.25^{d}
2.5	7.45	8.32	10.52	11.28^{a}	2389.12^{b}	4018.25^{c}
5.0	7.66	8.62	10.19	11.31^{a}	2606.00^{b}	5413.83^{b}
7.5	7.57	8.63	10.47	11.52^{a}	3066.10^{a}	6955.17^{a}
LS	NS	0.14	NS	*	**	**
SE±	0.12	0.14	0.16	0.17	81.38	131.09
Interaction						
NPK x CDM	NS	NS	NS	NS	**	**

Means followed by the same letter(s) are not significantly different at 5% level of probability according to DMR Test. LS=Level of significance; **and *=Significant at 1and 5%; NS=Not significant

On the other hand, CDM application had no significant ($P > 0.05$) effect on pod length across both seasons or pod diameter in 2019 but significantly increased pod thickness compared to the control in 2020, indicating improved pod quality. Additionally, the significant rise in pod yield with CDM application underscores its role in enhancing productivity. The highest yield recorded with 7.5 t ha^{-1} CDM in both seasons (3066.10 kg ha^{-1} in 2019 and 955.17 kg ha^{-1} in 2020) suggests this rate provides optimal nutrient availability for okra growth. However, seasonal yield variations indicate possible environmental influences on nutrient efficiency. These findings highlight the benefits of organic fertilization in improving okra yield and pod quality, positioning CDM as a viable alternative or supplement to synthetic fertilizers for sustainable production. This study aligns with Kamunyu *et al*. (2023), who found that applying 5-7 t ha^{-1} of poultry, cattle, or goat manure significantly increased okra yield and pod quality by enhancing soil nutrients and microbial activity. Similarly, Olowokere *et al.* (2021) reported that composted cow dung at 10-30 t/ha improved pod thickness, length, and overall yield, reinforcing the role of organic amendments in sustainable okra production.

The interaction between NPK and CDM on total pod yield was highly significant ($P < 0.001$), as shown in Table 4, where the combined application of 200 kg ha^{-1} NPK and 7.5 t ha^{-1} CDM resulted in the highest yields (4367.00 kg ha^{-1} in 2019 and 9148.00 kg ha^{-1} in 2020). This suggests that integrating organic and inorganic fertilizers provides a balanced and efficient nutrient supply, enhancing crop productivity. In contrast, the lowest yields recorded with the 0 × 0 combination (888.00 kg ha^{-1} in 2019 and 1889.00 kg ha^{-1} in 2020) highlight the detrimental impact of nutrient deficiency on okra production. The variation in yield between seasons also indicates potential environmental influences on nutrient uptake and efficiency. These findings align with Akinmutimi *et al.* (2023), who reported that combining poultry manure and NPK fertilizer significantly improved okra growth and yield compared to sole applications or control treatments. Similarly, Adekiya *et al*. (2020) and Mondai *et al*. (2022) in their separate studies found that organic manure sources outperformed NPK fertilizer in enhancing soil properties and okra productivity, reinforcing the importance of integrating organic and inorganic fertilizers. This confirms that the synergistic use of organic and synthetic fertilizers optimizes nutrient availability, leading to higher okra yields and sustainable agricultural production.

Conclusıon And Recommendatıon

This study demonstrated that the combined application of NPK fertilizer and cow dung manure significantly improves okra yield and yield components. The highest pod yield was obtained with the interaction of 200 kg ha^{-1} NPK and 7.5 t ha^{-1} CDM, highlighting the effectiveness of integrated nutrient management. While pod size showed seasonal variability, pod yield consistently increased with appropriate fertilization. The results suggest that balanced nutrient supply from organic and inorganic fertilizers enhances soil fertility and maximizes crop productivity. The findings emphasize the need for sustainable soil fertility management to ensure long-term agricultural productivity in the Sudan Savanna region of Nigeria. Therefore, to maximize okra yield, farmers in the study region should adopt integrated nutrient management by applying 200 kg ha^{-1} NPK and 7.5 t ha^{-1} CDM.

Table 4: Interaction of NPK and Cow dung manure on Total pod yield of Okra at BUK during 2019 and 2020 wet season

Treatment	Cow dung Manure (t ha^{-1}) 0	2.5	5.0	7.5
NPK (kg ha^{-1})		2019		
0	888.00^{o}	1267.00^{mn}	2214.00^{g-k}	2522.00^{f-h}
100	1517.00^{mn}	2239.00^{fghi}	2450.00^{f-i}	3185.00^{cd}
200	1619.00^{klm}	2570.00^{c}	3218.00^{c}	4637.00^{a}
300	2768.00^{cde}	3481.00^{b}	2542.00^{fg}	1918.00^{h-l}
LS		**		
SE±		162.75		
		2020		
0	1889.00^{o}	3792.00^{jk}	5898.00^{cd}	6381.00^{bc}
100	2458.67^{no}	3333.00^{klm}	5177.00^{d-g}	6884.33^{b}
200	2862.33^{mn}	4098.00^{ij}	5359.04^{de}	9148.00^{a}
300	3459.00^{j-l}	4850.00^{e-i}	5133.33^{d-h}	5407.33^{d}
LS		**		
SE±		262.18		

Means followed by same letter(s) are not significantly different at 5% level of probability according to SNK Test.

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Optimizing Okra (*Abelmoschus esculentus*) Productivity through Integrated Nutrient Management: Effects of NPK Fertilizer and Cow Dung Manure in the Sudan Savanna, Nigeria

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Abstract

This study evaluated the influence of NPK fertilizer and cow dung manure (CDM) on okra (*Abelmoschus esculentus*) yield and its components under the Sudan Savanna conditions of Nigeria. A 4 × 4 factorial experiment in a randomized complete block design with four replications was conducted at Teaching and Research farm, Bayero University, Kano. Treatments included four levels each of NPK fertilizer (0, 200, 300, and 400 kg ha^{-1}) and CDM (0, 2.5, 5.0, and 7.5 t ha^{-1}). Results indicated that NPK and CDM significantly ($P < 0.001$) influenced pod yield, with the highest yields obtained at 200 kg ha^{-1} NPK and 7.5 t ha^{-1} CDM (4367.00 kg ha^{-1} in 2019 and 9148.00 kg ha^{-1} in 2020), representing a 391% and 384% increase, respectively, over the control (888.00 kg ha^{-1} in 2019 and 1889.00 kg ha^{-1} in 2020). Pod length increased significantly ($P < 0.001$) with 100–200 kg ha^{-1} NPK in 2019 but was not significantly affected in 2020, suggesting seasonal variability. CDM at 7.5 t ha^{-1} produced the highest pod count (18.47 in 2019 and 24.73 in 2020), outperforming lower rates. The findings underscore the benefits of integrated nutrient management, as the combination of NPK and CDM enhanced soil fertility, increased pod number, and improved total yield. These results confirm that organic and inorganic fertilizers complement each other in optimizing okra productivity. Thus, integrated nutrient management using 200 kg ha^{-1} NPK and 7.5 t ha^{-1} CDM could be adopted by the farmers for sustainable okra production in nutrient-deficient soils of the Sudan Savanna region.

Keywords: *Fertilization strategy, okra, yield optimization, soil fertility, Sudan savanna*

Introductıon

Okra (*Abelmoschus esculentus* L. Moench) is an economically important vegetable crop widely cultivated in tropical and subtropical regions, including Nigeria. It is rich in vitamins, minerals, and antioxidants, making it an essential part of human nutrition (Ibitoye and Kolawole, 2022). However, the yield of okra in the Sudan Savanna ecology of Nigeria remains low due to poor soil fertility and inadequate nutrient management practices (Hamisu *et al.,* 2021). Integrated Nutrient Management (INM), incorporating the principles of Integrated Soil Fertility Management (ISFM), is a sustainable approach to enhancing soil health, crop productivity, and long-term agricultural viability (Pathan *et al.,* 2024). By combining organic and inorganic fertilizers, this approach optimizes nutrient availability, where organic amendments improve soil structure and microbial activity, while inorganic fertilizers provide essential nutrients for plant growth (Liu *et al.,* 2024). Additionally, Justus von Liebig's law of the minimum states that plant growth is limited by the most deficient nutrient, reinforcing the need for balanced fertilization to maximize okra yield (Bimpe *et al.,* 2023).

Despite the importance of okra in Nigeria, its yield remains suboptimal due to nutrient depletion, poor soil fertility, and over-reliance on synthetic fertilizers (Badu Brempong and Addo-Danso, 2022). Conventional fertilization methods often lead to soil degradation, nutrient imbalances, and declining crop productivity (Akter *et al*., 2020; Ayodele *et al*., 2020). Additionally, excessive use of inorganic fertilizers contributes to environmental pollution and increased production costs (Abdalla *et al*., 2024). The limited adoption of integrated nutrient management strategies in the Sudan Savanna region exacerbates the problem, necessitating research on the most effective nutrient management approach to enhance okra yield while maintaining soil health.

Previous studies indicate that INM enhances soil structure, microbial activity, and nutrient availability, leading to higher crop productivity (Yusuf *et al*., 2020; Gupta *et al.,* 2022). However, in the Sudan Savanna region, erratic rainfall, high temperatures, and nutrient-deficient soils pose significant challenges to crop production (Olowolafe and Dibal, 2019), highlighting the need to assess INM's impact on okra yield and its components to optimize nutrient management for sustainable agriculture in Nigeria. This study aims to evaluate the impact of different rates of NPK fertilizer and CDM on the yield and yield components of okra under Sudan Savanna conditions.

Materials And Methods

The trials were conducted at the Teaching and Research Farm of Bayero University, Kano (Latitude 11° 58.861'N and Longitude 08° 31.177'E, with altitude of 476m above sea level). The experimental field was properly cleared of debris ad stumps. The land was then ploughed, harrowed to fine tilt and ridged. The field was demarcated into three replicates consisting of sixteen plots of gross plot size of 3 m x 3 m (9 m^2) and a net plot of 3 m x 1.5 m (4.5 m^2) which consists of the two inner rows. A pathway of 0.5 m and 1.0 m was between plots and replication was maintained to provide ease of movement and prevent nutrient drift. The experiment was a 4 x 4 factorial combination laid out in a randomized complete block design with four replications. The treatments comprised of varied rates of NPK fertilizer (0, 200, 300, and 400 kg ha^{-1}) and cow dung manure (CDM) (0, 2.5, 5.0, and 7.5 t ha^{-1}), resulting in 16 treatment combinations.

The okra seeds variety NHB-AI-13 was sourced from the National Horticultural Research (NIHORT) substation, Bagauda, Kano state. The cow dung was sourced from the livestock unit of the department of Animal Science of Bayero University Kano while the NPK fertilizer was from the department of Agronomy, BUK. The cow dung manure was applied as a basal application by broadcasting and incorporating it into the soil two weeks prior to sowing for ease of decomposition and to allow CO_2 escape, thus preventing scorching of the tender okra seedlings. NPK fertilizer (15-15-15) was applied according to the designated rates at 2 WAS about 10 cm radius away from the plant stand using ring method. For the treatments without CDM and NPK, no manure was applied throughout the growing season.

Three to four seed s of okra (NBH-AI-13) were sown directly into the soil at a depth of 2 cm with a spacing of 30 cm x 30 cm. the seedlings were later thinned to one plant per stand at 2 WAS. The crops were managed using standard agronomic practices for okra cultivation, including weeding, and pest control. Weeding was done manually as at when due using hoe. The defoliating insect pest were managed using Lampda (Cyhalothrin 2.5 EC) a contact insecticide applied at 2 L ha^{-1} using Cp3 knapsack sprayer set at a pressure of 2.1 kg m^{-2}.
Data were collected using standard agronomic procedure on the following yield component and yield of okra: Number of pods per plant, Individual pod weight, pod length, pod diameter and total pod yield (kg ha^{-1}). All data collected was subjected to analysis of variance (ANOVA) using SAS (Version 9.1) and significant means were separated using Duncan Multiple Range Test (DMRT) at 5% probability level.

Results And Dıscussıon

Effects of NPK Fertilizers and Cow dung manure on pods count per plant and pod weight per plant
Table 1 presents the effect of NPK fertilizer and cow dung manure (CDM) on the pods count per plant and individual pod weight of okra during the 2019 and 2020 wet seasons. The results show that while both inputs significantly ($P < 0.001$) influenced pod number, they had no significant ($P > 0.05$) effect on individual pod weight. Higher pods count were recorded with NPK application (100-300 kg ha^{-1}), whereas the control resulted in the lowest values across both seasons. Similarly, CDM at 7.5 t ha^{-1} produced the highest pod count, followed by 5.0 t ha^{-1}, outperforming lower rates in both years. The effectiveness of high-rate NPK in enhancing pods count highlights its role in promoting reproductive growth, while CDM's success at 7.5 t ha^{-1} suggests that organic fertilization is a viable alternative to synthetic fertilizers for increasing okra yield. This underscores the importance of balanced nutrient management, particularly in nutrient-deficient soils. These findings align with Muhammad and Sanda (2019), who reported that applying 800 kg ha^{-1} of NPK or a 50:50 combination of NPK and poultry manure significantly increased the number of pods per plant and overall yield. Similarly, Adekiya *et al*. (2020) found that poultry manure application improved okra pod production in comparison to sole NPK fertilizer.

The interaction between NPK and CDM on the pods count per plant was significant across both seasons, as shown in Table 2. The combined application of 200 kg ha^{-1} NPK and 7.5 t ha^{-1} CDM produced the highest pods count per plant in 2019 (18.47) and 2020 (24.73), outperforming other treatment combinations. This suggests that integrating organic and inorganic fertilizers creates a more balanced nutrient supply, enhancing pod formation and overall productivity. These findings align with those of Meena (2024), who reported that combining organic and inorganic fertilizers improved fruit set and pod production in okra. Similarly, Karim *et al.* (2024) found that integrating mineral fertilizers with organic amendments significantly enhanced crop yield by improving soil nutrient availability and plant growth. These results reinforce the benefits of integrated nutrient management in optimizing okra production through improved soil fertility and plant performance.

Table 1: Effect of NPK and Cow dung manure on pods count per plant and pod weight per plant of Okra at BUK during 2019 and 2020 wet season

Treatment	Pods count Plant-1 (#)		Individual Pod weight (g)	
	2019	2020	2019	2020
NPK (kg ha-1)				
0	9.65[b]	12.82[c]	22.86	39.25
100	11.36[a]	15.23[ab]	26.10	39.91
200	12.53[a]	16.23[a]	24.25	43.91
300	11.87[a]	14.73[b]	26.18	44.16
LS	**	**	NS	NS
SE±	0.46	0.43	2.45	1.89
Cowdung Manure (t ha-1) [CDM]				
0	9.38[c]	11.86[c]	20.01	41.42
2.5	9.83[c]	12.98[bc]	26.60	42.83
5.0	11.21[b]	14.23[h]	25..04	41.75
7.5	15.00[a]	19.94[a]	27.75	41.25
LS	*	**	NS	NS
SE±	0.46	0.43	2.45	1.89
Interaction				
NPK x CDM	**	**	NS	NS

Means followed by the same letter(s) are not significantly different at 5% level of probability according to DMR Test. LS=Level of significance; **and *=Significant at 1and 5%; NS=Not significant

Table 2: Interaction of NPK and Cow dung manure on Pods count per plant of Okra during 2019 and 2020 wet season

Treatment	Cow dung Manure (t ha-1)			
	0	2.5	5.0	7.5
NPK (kg ha-1)		2019		
0	6.97[no]	7.13[j-o]	11.40[c-g]	13.10[bcd]
100	12.10[b-e]	8.43[i-o]	10.87[d-i]	13.97[bc]
200	10.07[e-m]	11.13[d-h]	10.47[d-k]	18.47[a]
300	10.10[e-l]	10.80[d-j]	12.10[b-f]	14.47[b]
LS		**		
SE±		0.92		
		2020		
0	8.93[im]	13.13[fgh]	12.73[f-i]	16.47[c]
100	13.50[f]	13.37[fg]	12.67[f-j]	21.40[b]
200	11.67[f-k]	12.67[f-j]	16.40[cd]	24.73[a]
300	13.33[fg]	12.73[f-i]	15.10[de]	17.73[c]
LS		**		
SE±		0.87		

Means followed by same letter(s) are not significantly different at 5% level of probability according to SNK Test.

Effects of NPK Fertilizers and Cow dung manure on Pod length, Pod diameter, and Total pod yield per hectare. The effects of NPK and CDM rates on pod length, pod diameter, and total pod yield of okra in the 2019 and 2020 seasons are presented in Table 3. Results show that applying 100 and 200 kg/ha NPK significantly ($P < 0.001$) increased pod length in 2019 but had no significant ($P > 0.05$) effect in 2020, suggesting seasonal variability in nutrient response. Similarly, pod diameter was not significantly affected in either season, indicating that factors such as genetics, soil conditions, and environmental variables may play a more dominant role than nutrient application alone. However, the significant increase in total pod yield (3011.14 & 3011.14 kg ha^{-1}) with 200 kg ha^{-1} NPK application across both seasons highlights the importance of adequate nutrient supply in enhancing productivity. This suggests that while pod size may not be directly influenced, optimizing NPK application can significantly boost total yield, making it essential for maximizing okra production. These findings align with Esmond *et al*. (2023), who reported a significant increase in okra pod weight and yield with higher NPK rates, while Sabo and Zubairu (2021) and Sababa *et al.* (2024), who found that optimal NPK and NPS fertilizer rates

improved pod length and yield, reinforcing the role of proper nutrient management in enhancing okra productivity, respectively.

Table 3: Effect of NPK and Cow dung manure on Pod length, Pod diameter and Total pod yield of Okra at Bauchi during 2019 and 2020 wet season

Treatment	Pod length (cm)		Pod diameter (cm)		Total pod yield (Kg ha^{-1})	
	2019	2020	2019	2020	2019	2020
NPK (kg ha^{-1})						
0	7.31^{b}	8.21	10.40	10.99	1715.10^{d}	2490.00^{c}
100	7.99^{a}	8.39	10.69	11.26	2348.21^{c}	4463.25^{b}
200	7.65^{a}	8.43	10.34	11.16	3011.14^{a}	5366.83^{a}
300	7.51^{b}	8.58	10.34	11.23	2678.10^{b}	4712.42^{b}
LS	**	NS	0.16	0.17	**	**
SE±	0.12	0.14	NS	NS	81.38	131.09
Cow dung Manure [CDM] (t ha^{-1})						
0	7.75	8.12	10.59	10.58^{b}	1690.20^{c}	2671.25^{d}
2.5	7.45	8.32	10.52	11.28^{a}	2389.12^{b}	4018.25^{c}
5.0	7.66	8.62	10.19	11.31^{a}	2606.00^{b}	5413.83^{b}
7.5	7.57	8.63	10.47	11.52^{a}	3066.10^{a}	6955.17^{a}
LS	NS	0.14	NS	*	**	**
SE±	0.12	0.14	0.16	0.17	81.38	131.09
Interaction						
NPK x CDM	NS	NS	NS	NS	**	**

Means followed by the same letter(s) are not significantly different at 5% level of probability according to DMR Test. LS=Level of significance; **and *=Significant at 1and 5%; NS=Not significant

On the other hand, CDM application had no significant ($P > 0.05$) effect on pod length across both seasons or pod diameter in 2019 but significantly increased pod thickness compared to the control in 2020, indicating improved pod quality. Additionally, the significant rise in pod yield with CDM application underscores its role in enhancing productivity. The highest yield recorded with 7.5 t ha^{-1} CDM in both seasons (3066.10 kg ha^{-1} in 2019 and 955.17 kg ha^{-1} in 2020) suggests this rate provides optimal nutrient availability for okra growth. However, seasonal yield variations indicate possible environmental influences on nutrient efficiency. These findings highlight the benefits of organic fertilization in improving okra yield and pod quality, positioning CDM as a viable alternative or supplement to synthetic fertilizers for sustainable production. This study aligns with Kamunyu *et al*. (2023), who found that applying 5-7 t ha^{-1} of poultry, cattle, or goat manure significantly increased okra yield and pod quality by enhancing soil nutrients and microbial activity. Similarly, Olowokere *et al.* (2021) reported that composted cow dung at 10-30 t/ha improved pod thickness, length, and overall yield, reinforcing the role of organic amendments in sustainable okra production.

The interaction between NPK and CDM on total pod yield was highly significant ($P < 0.001$), as shown in Table 4, where the combined application of 200 kg ha^{-1} NPK and 7.5 t ha^{-1} CDM resulted in the highest yields (4367.00 kg ha^{-1} in 2019 and 9148.00 kg ha^{-1} in 2020). This suggests that integrating organic and inorganic fertilizers provides a balanced and efficient nutrient supply, enhancing crop productivity. In contrast, the lowest yields recorded with the 0 × 0 combination (888.00 kg ha^{-1} in 2019 and 1889.00 kg ha^{-1} in 2020) highlight the detrimental impact of nutrient deficiency on okra production. The variation in yield between seasons also indicates potential environmental influences on nutrient uptake and efficiency. These findings align with Akinmutimi *et al.* (2023), who reported that combining poultry manure and NPK fertilizer significantly improved okra growth and yield compared to sole applications or control treatments. Similarly, Adekiya *et al*. (2020) and Mondai *et al*. (2022) in their separate studies found that organic manure sources outperformed NPK fertilizer in enhancing soil properties and okra productivity, reinforcing the importance of integrating organic and inorganic fertilizers. This confirms that the synergistic use of organic and synthetic fertilizers optimizes nutrient availability, leading to higher okra yields and sustainable agricultural production.

Table 4: Interaction of NPK and Cow dung manure on Total pod yield of Okra at BUK during 2019 and 2020 wet season

	Cow dung Manure (t ha^{-1})			
Treatment	0	2.5	5.0	7.5

NPK (kg ha^{-1})				
		2019		
0	888.00^{o}	1267.00^{mn}	2214.00^{g-k}	2522.00^{f-h}
100	1517.00^{mn}	2239.00^{fghi}	2450.00^{f-i}	3185.00^{cd}
200	1619.00^{klm}	2570.00^{c}	3218.00^{c}	4637.00^{a}
300	2768.00^{cde}	3481.00^{b}	2542.00^{fg}	1918.00^{h-l}
LS		**		
SE±		162.75		
		2020		
0	1889.00^{o}	3792.00^{jk}	5898.00^{cd}	6381.00^{bc}
100	2458.67^{no}	3333.00^{klm}	5177.00^{d-g}	6884.33^{b}
200	2862.33^{mn}	4098.00^{ij}	5359.04^{de}	9148.00^{a}
300	3459.00^{j-l}	4850.00^{e-i}	5133.33^{d-h}	5407.33^{d}
LS		**		
SE±		262.18		

Means followed by same letter(s) are not significantly different at 5% level of probability according to SNK Test.

Conclusıon And Recommendatıon

This study demonstrated that the combined application of NPK fertilizer and cow dung manure significantly improves okra yield and yield components. The highest pod yield was obtained with the interaction of 200 kg ha^{-1} NPK and 7.5 t ha^{-1} CDM, highlighting the effectiveness of integrated nutrient management. While pod size showed seasonal variability, pod yield consistently increased with appropriate fertilization. The results suggest that balanced nutrient supply from organic and inorganic fertilizers enhances soil fertility and maximizes crop productivity. The findings emphasize the need for sustainable soil fertility management to ensure long-term agricultural productivity in the Sudan Savanna region of Nigeria. Therefore, to maximize okra yield, farmers in the study region should adopt integrated nutrient management by applying 200 kg ha^{-1} NPK and 7.5 t ha^{-1} CDM.

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Enhancing Food Productivity through Intensive Agroforestry Cropping for Sustainable Soil Practices – A Review

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Abstract

Adoption of sustainable agriculture through agroforestry systems presents a viable solution to address declining soil fertility, land degradation, and food insecurity in Bangladesh. This review focuses on intensive agroforestry systems characterized by high density, multispecies cropping and their potential to improve crop yield, restore soil health, and enhance ecosystem services. Agroforestry practices such as homestead gardening, multi-storey cropping, orchard based systems, and boundary plantations contribute to nutrient cycling, biodiversity conservation, and climate resilience. However, widespread use of chemical fertilizers continues to degrade soil quality and diminish productivity. Integrating organic and bio fertilizers within an integrated nutrient management (INM) framework offers a sustainable alternative that improves soil structure, increases nutrient availability, and supports long term agricultural productivity. The review also emphasizes the importance of policy interventions to promote balanced fertilizer use, incentivize sustainable practices, and enhance extension services. Furthermore, regionally informed strategies and insights from global models can guide the effective adoption of agroforestry in Bangladesh. This review highlights intensive agroforestry and diversified fertilizer management as practical pathways to achieving sustainable food production, ecological balance, and rural livelihood improvement.

Keywords: *Agroforestry, Intensive Cropping, Fertilizer Types, Food Production, Soil Health*

Introduction

The current global food crisis highlights the urgent need for sustainable development strategies that enhance food production and ensure food security particularly in densely populated countries like Bangladesh (Talucder et al., 2024). Rising demand for food, however, has accelerated soil degradation and environmental decline, posing significant threats to long term agricultural productivity (Ray & Ray, 2011). Bangladesh, with a population exceeding 165 million and a land area of only 147,570 km², has among the world's lowest per capita availability of arable (0.06 ha) and forest land (0.02 ha) (Hasan et al., 2013; BBS, 2019). Furthermore, 21.8% of the population lives in poverty, with over 87% of the poor residing in rural areas where livelihoods are heavily reliant on tree and cropbased farming systems (Islam et al., 2015). Land degradation presents a major threat to sustainable food systems. Each year, more than 23,000 hectares of cultivable land are lost to infrastructure expansion, urban sprawl, and rural settlement growth extremely affecting smallholder farmers and intensifying pressure on remaining agricultural land (Hasan et al., 2013). Between 1989 and 2020, the share of arable land fell from 73.4% to 61.5% (Ahsan et al., 2023), and projections suggest that rapid urbanization and industrial growth could result in an annual loss of approximately 69,000 hectares of farmland (Khan, 2023). These trends exacerbate land scarcity and threaten Bangladesh's capacity to meet the growing demand for food and nutrition.

Soil, a finite and non-renewable resource crucial to food production, is increasingly being depleted due to unsustainable land management practices. Healthy soils are essential for poverty alleviation and food security, as they enhance crop yields and reduce vulnerability to pests and diseases (FAO, 2017; Hou et al., 2020). Over the past five decades, global food production has declined by 11.9–13.4% due to soil degradation (Jie et al., 2002). In South Asia, including Bangladesh, soil degradation is particularly severe 140 million hectares of land are impacted by groundwater depletion, erosion, waterlogging, and nutrient loss (Jahan & Gurung, 2017), resulting in an estimated annual GDP loss of 2% (USD 10 billion) due to land degradation (Niino, 2011). The situation is especially dire in south eastern Bangladesh, where land degradation is compounded by steep topography (Chowdhury et al., 2023). However, the Green Revolution initially boosted yields through high yield crop varieties, intensive tillage, and chemical inputs, these practices have also led to long term soil fatigue and nutrient depletion.

Continuous monoculture and input intensive methods have rendered 74.2% of Bangladesh's soils deficient in key nutrients, undermining productivity and climate resilience (Sharna et al., 2022; Barbier & Hochard, 2018).
Agroforestry integrating trees with crops and/or livestock on the same land unit offers a promising and sustainable alternative. It has been recognized for enhancing livelihoods, improving climate resilience, and supporting food and nutritional security (Islam et al., 2013). Research by Allen et al. (2004) and Mukhlis et al. (2022) has shown that agroforestry can rehabilitate degraded land and enhance ecosystem services by improving the physical, chemical, and biological properties of soil through mechanisms such as litter deposition and root activity. Nevertheless, much of the existing research focuses primarily on biophysical outcomes, with limited attention to the socioeconomic dimensions of agroforestry particularly within the Bangladeshi context (Atangana et al., 2013). Recently, orchard based systems particularly in districts like Dinajpur have gained popularity due to their economic returns and potential to enhance soil health. However, many of these orchards lack integrated management practices, such as intensive understory cropping, that could maximize land use efficiency. Sustainable orchard management through multispecies understory cropping and improved nutrient practices could significantly enhance productivity, stabilize income, and rehabilitate soil health for smallholder farmers.
This review aims to fill the knowledge gap surrounding sustainable, orchard based agroforestry systems in north western Bangladesh. Specifically, it evaluates the potential of intensive understory cropping to improve soil health, examines current fertilizer management practices, and proposes sustainable strategies to enhance productivity within agroforestry frameworks. Addressing these factors is essential for improving the long term sustainability of agroforestry, ensuring food security, promoting ecological restoration, and supporting resilient rural livelihoods.

Food Production Patterns in Bangladesh

Bangladesh's fertile soils and favourable agro climatic conditions support the production of over 70 million tonnes of agricultural output annually, with more than 70% of the country's land area devoted to agricultural use (BIDA, 2021). The primary crops cultivated include rice, jute, wheat, potatoes, fruits, vegetables, legumes, and oilseeds. Among these, rice is the most dominant, occupying approximately 71% of the total cultivated land and contributing 59% to the overall crop value. Potatoes follow as the second most valuable crop, accounting for 9.5% of total crop value (Barois et al., 2024). Moreover, in the livestock and aquaculture sectors, fish and crayfish dominate animal production, comprising 73% of total output, with aquaculture alone contributing 68% of fish production. Goat farming ranks second in meat production value at around 6% (FAO, 2023a). The agriculture sector including crops, fisheries, and forestry employs approximately 40.6% of the labor force aged 15 and older. Smallholder farmers represent the backbone of the agricultural economy, with about 12 million farms supporting 60 million people and producing roughly 60% of the nation's food. The average farm size is just 0.24 hectares, and most households engage in integrated farming systems that combine rice cultivation with one to two additional crops and livestock rearing (Barois et al., 2024).

Status of Food Security in Bangladesh
Bangladesh has made measurable progress in food and nutrition security over recent years. The prevalence of moderate and severe food insecurity declined slightly from an average of 32.2% during 2014–2016 to 31% in 2020–2022, even as food insecurity increased significantly across South Asia, rising from 27.6% to 41.3% during the same period (Barois et al., 2024). Despite this progress, the country remains heavily reliant on food imports to meet the nutritional needs of its growing population. As of 2015, food imports constituted approximately 17% of total merchandise imports, whereas food exports accounted for just 3%, underscoring a considerable trade imbalance (World Bank, 2015). This reliance on traditional, subsistence based agriculture limits opportunities for commercialisation and poses risks to long term food sovereignty. These challenges highlight the urgent need for sustainable, resource efficient agricultural practices that can reduce import dependence and bolster national food security.

Soil Fertility and Soil Health Status in Bangladesh
To sustain crop productivity, farmers in Bangladesh have increasingly depended on chemical fertilisers urea alone accounting for approximately 75% of total fertiliser use (Shil et al., 2016). However, this intensive use of synthetic inputs has contributed to declining soil quality. Organic matter levels in most agricultural soils remain critically low, with values below the recommended 1.5%, and saw a 5–36% decline between 1967 and 1995. Furthermore, recent assessments indicate that nearly 47% of farmers misuse fertilisers, which not only compromises soil health but also poses environmental and human health risks (Barois et al., 2024).Therefore, soil fertility remains poor across much of the country, with the exception of a few Agro Ecological Zones (AEZs 10, 12, 13, and parts of 11), which exhibit comparatively better conditions. This widespread degradation necessitates immediate and strategic intervention. Promoting sustainable land management practices such as the use of organic and biofertilisers, crop rotation, and ecologically integrated approaches like intensive agroforestry can help restore soil

fertility, enhance soil structure, and reduce dependence on synthetic inputs. Strengthening farmer awareness, along with institutional and policy support, will be essential for ensuring long term soil health and agricultural sustainability (Barois et al., 2024).

Contributions of Agroforestry Practices to Soil Health Improvement

Agroforestry has emerged as a vital land use strategy in many developing countries, including Bangladesh, offering smallholder farmers a means to enhance ecological resilience, farm productivity, and biodiversity. By integrating trees with crops, agroforestry systems play a critical role in preventing soil degradation while simultaneously boosting agricultural yields. These systems enrich soil organic matter, increase soil carbon content, and improve the availability and cycling of key nutrients such as nitrogen (N), phosphorus (P), and potassium (K) (Islam et al., 2024). As such, agroforestry offers a promising and sustainable pathway for restoring soil fertility and supporting broader environmental conservation efforts.

Traditional or extensive agroforestry systems have long been practiced across diverse ecological zones in Bangladesh. As noted by Nair (1990), these systems are well adapted to the rural livelihood needs and local environmental conditions of the country. Practices such as homestead gardening, boundary planting, alley cropping, and silvopasture have developed organically, shaped by local variations in soil type, rainfall, topography, and socioeconomic context. According to Islam et al. (2024), these low input systems provide multiple ecosystem services, including food, fodder, fuelwood, and timber, while enhancing climate resilience and conserving natural resources at the community level. In contrast, intensive agroforestry systems are designed to optimise land productivity by employing multistory canopy structures and increasing both tree and crop density. These systems often incorporate fast growing, multifunctional species such as *Grevillea robusta* and are structured to promote vertical layering, year round output, and ecological synergy (Keerthika et al., 2024). Unlike traditional systems that emphasize subsistence and minimal management, intensive agroforestry is driven by goals of yield maximisation, ecological sustainability, and revenue diversification, often employing precision agriculture and "smart" farming techniques (Leakey, 1999). This approach is particularly relevant for land scarce countries like Bangladesh, where efficient land use is paramount.

Despite its advantages, the adoption of intensive agroforestry remains limited in Bangladesh, particularly concerning its long term impact on soil health under the country's subtropical monsoon climate. However, ecosystem services such as enhanced biodiversity, regulated soil moisture, and biomass recycling suggest that even low input intensive systems can deliver significant environmental benefits. Expanding research and field implementation of these systems could unlock their full potential in sustainable land management and agricultural productivity enhancement.

Table 1: Key differences between traditional and intensive agroforestry systems

Futures	**Traditional Agroforestry systems**	**Intensive agroforestry systems**
Input level	Low to moderate	High
Purpose	Farmer food security, income and ecological balance	Industrial production such as tea and cocoa
Management	Traditional	Precision or smart practice
Scale	subsistence	Commercial
Output	Moderately diversified	Highly diversified
Examples	Homestead, cropland, silvopasture, alley cropping etc.	Fodder bank, tea garden, bioenergy, timber, food chain processing etc.

Trends and Challenges of Agroforestry in Bangladesh

Agroforestry has deep historical roots in rural Bangladesh, particularly within smallholder and homestead systems. Traditionally, these practices have supported household food security, biodiversity conservation, and cultural continuity while providing essential resources such as fuel, timber, and supplementary income (Ahsan & Begum, 2023). Common forms such as boundary planting and scattered tree cultivation within croplands continue to enhance local climate resilience and diversify livelihoods (Hanif et al., 2018). Studies on agroforestry have received growing attention from the government and development partners as a viable strategy to meet socioeconomic and environmental objectives. Nevertheless, most institutional efforts and policy initiatives have focused on promoting conventional agroforestry models, with limited emphasis on research, extension, or promotion of intensive approaches. Although there is considerable potential for diverse, site specific systems across agroecological zones including the Chittagong Hill Tracts, floodplains, and coastal regions systematic

adoption of high density, intercropped agroforestry remains limited (Bari et al., 2024). Several structural challenges constrain the widespread adoption of intensive agroforestry in Bangladesh. These include the absence of integrated policy frameworks and scientific validation tailored to the complex, multispecies nature of such systems. Extension services are often inadequate, limiting farmers' access to high quality planting materials, technical support, and training. Furthermore, weak market linkages, poor knowledge dissemination mechanisms, and insufficient farmer engagement hinder the replication of successful models. A critical gap also persists in interdisciplinary research that integrates ecological, agronomic, and socioeconomic dimensions particularly studies involving long term soil monitoring. Addressing these gaps is essential for advancing a nuanced understanding of how intensive agroforestry systems affect soil fertility, resource use efficiency, and rural livelihoods, thereby enabling the development of scalable and sustainable land use strategies.

Role of Intensive Agroforestry Systems in Food Security and Sustainability

Intensive agroforestry systems significantly contribute to food security and sustainable agriculture by promoting dynamic interactions among crops, trees, and soil organisms. As Bhaduri et al. (2017) note, these interactions enhance biological, chemical, and physical soil processes, leading to increased agricultural productivity and improved soil health. Trees incorporated into farmland contribute organic matter through leaf litter and root biomass, stimulating soil organic carbon (SOC) accumulation. Higher SOC levels, in turn, improve microbial activity, enhance soil structure, and increase water holding capacity all vital attributes for long term agricultural sustainability. One of the hallmark features of agroforestry is the use of nitrogen fixing leguminous tree species, which naturally enrich the soil and reduce dependence on synthetic fertilisers (Sileshi et al., 2014). Additionally, the deep rooted nature of many agroforestry species facilitates a process known as “nutrient pumping,” whereby nutrients are absorbed from subsoil layers and redistributed to the surface through litter fall and root turnover (Garrity & Lefroy, 1994). This nutrient recycling enhances topsoil fertility and promotes higher crop yields over time.

Agroforestry also confers significant physical protection to the soil. Tree canopies reduce the erosive impact of rainfall, while their extensive root systems help stabilise soil, thereby mitigating erosion an especially critical service in Bangladesh’s flood and cyclone prone regions (Zuazo & Pleguezuelo, 2009). Furthermore, shaded microclimates created by tree cover help moderate soil temperature, retain moisture, and foster beneficial microbial communities such as mycorrhizal fungi, which facilitate nutrient mineralisation and suppress soil pathogens (Sileshi et al., 2014). This intensive system indicate that root density and biomass turnover are high thereby improve the ecological functions significantly. The synergy between woody perennials and annual crops not only rejuvenates degraded soils and reduces chemical input requirements but also builds resilient agroecosystems. In the context of Bangladesh, such systems represent a vital pathway for enhancing food security, improving soil sustainability, and supporting climate adaptation.

Table 2: Comparative impact of cropping systems on key sustainability parameters

Parameters	**Mono cropping**	**Traditional Agroforestry**	**Intensive Agroforestry**
Soil fertility	Decline over time	Regulators	Significantly improves
Carbon sequestration	Minimal(0.51 t c/ha/yr)	Moderate (2.4 t c/ha/yr)	High (48 t C/ha/yr)
Biodiversity conservation	Very low	Medium	High
Climate resilience	Poor (vulnerable)	Moderate	High
Water retention	Low	Moderate	High
Overall Sustainability	Low	Medium to high	Very high

Yield Productivity Index under Different Cropping Systems

The comparative analysis of yield productivity indices across cropping systems reveals distinct differences in agricultural efficiency and sustainability. Among the systems, monocropping consistently demonstrates the lowest productivity index. This underperformance is primarily due to its inherent limitations dependence on a single crop species per season leads to rapid nutrient depletion, increased vulnerability to pest infestations, and accelerated soil degradation. Such systems also lack ecological redundancy, making them highly susceptible to climatic and market shocks. Traditional agroforestry systems show marginal improvements in productivity over monocropping. These systems involve limited integration of trees with crops, contributing to modest gains in soil health, biodiversity, and microclimate regulation. However, their productivity remains suboptimal due to low species diversity, inadequate spatial design, and limited management intensity. While they provide subsistence benefits and ecological services, their potential to enhance output is constrained by their extensive, low input nature. Comparatively, intensive agroforestry systems achieve the highest yield productivity index. These systems strategically combine high density, multispecies planting arrangements that utilise vertical stratification and

complementarity among species to maximise land use efficiency. Through mechanisms such as nutrient cycling, nitrogen fixation, and organic matter enrichment, intensive agroforestry significantly enhances soil fertility and resilience. It also supports year round production and greater economic returns through diversified outputs, including food, fodder, timber, and biomass. The superiority of intensive agroforestry in yield productivity underscores its potential as a climate adaptive, resource efficient, and sustainable agricultural model. This is particularly relevant for densely populated, resource constrained regions such as Bangladesh, where land scarcity, soil degradation, and food insecurity are persistent challenges. By integrating ecological principles with modern agronomic practices, intensive agroforestry can play a transformative role in ensuring long term productivity and rural livelihood resilience.

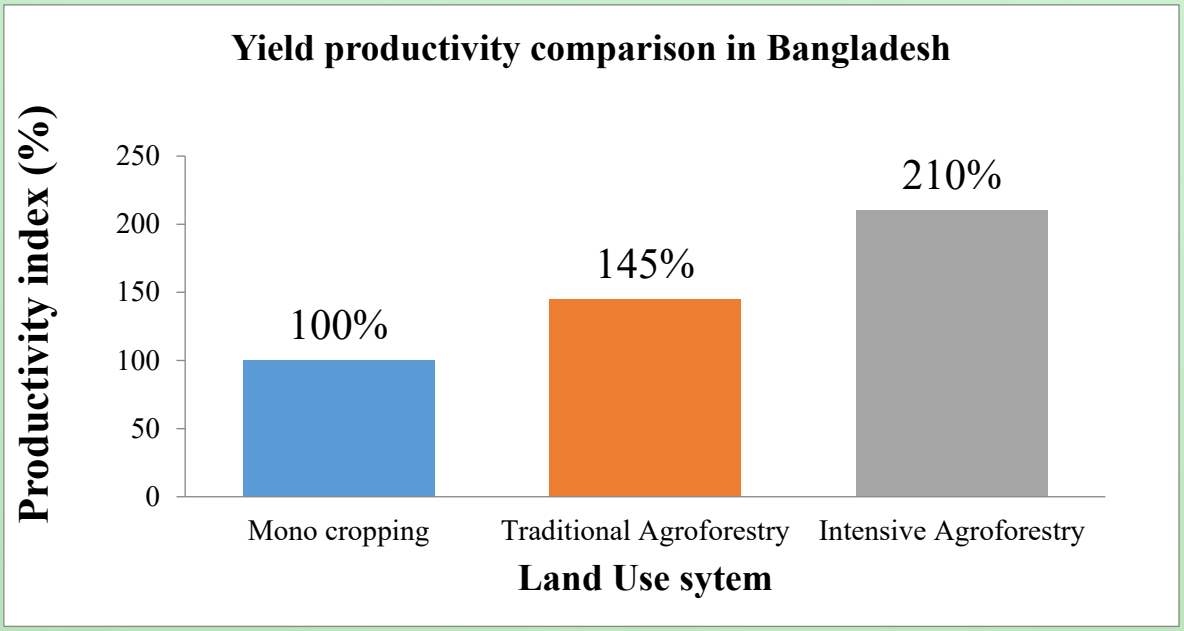


Figure 1: Yield Productivity index under different cropping systems
Source: (Islam, K.K., et al. 2024)

Food Production Potential under Different Cropping Systems

Intensive agroforestry systems have demonstrated significant potential for enhancing food production in Bangladesh, particularly among smallholder farmers operating on limited land resources. By integrating multiple crop species with perennial trees in spatially and temporally optimized arrangements, these systems consistently outperform conventional monoculture practices in terms of productivity per unit area (Rahman et al., 2015). Strategic pairings such as banana with vegetables or mango with pulses enable efficient vertical stratification and staggered harvesting cycles, thereby ensuring dietary diversity and more effective land use (Awasthi, 2018).

The synergistic relationships between trees and crops in intensive agroforestry systems result in higher aggregate caloric and protein yields compared to monocropping or traditional agroforestry (Mulugeta, 2014). These systems offer a year round food supply, mitigate seasonal food shortages, and enhance resilience to climate induced stresses such as droughts and floods. Moreover, the incorporation of fruit bearing and nitrogen fixing leguminous trees contributes to improved household nutrition while also generating supplementary income through the sale of marketable produce. Economic evaluations indicate that intensive agroforestry can deliver greater long term returns on investment than conventional cropping systems, despite moderately higher initial establishment costs (Van et al., 2016). Benefits such as enhanced soil fertility, reduced dependency on synthetic fertilisers, diversified income streams, and climate adaptability collectively contribute to the economic viability and sustainability of these systems. Their effectiveness is particularly evident in ecologically sensitive regions such as the coastal belts and the Chittagong Hill Tracts where they contribute to landscape rehabilitation and sustainable livelihoods (Saha et al., 2022).

The integration of sustainable management techniques including mulching, composting, and integrated pest management (IPM) further amplifies the productivity and ecological value of intensive agroforestry. These practices thrive in diverse cropping environments, reinforcing system resilience while reducing input costs and environmental risks. In the context of Bangladesh's land constraints and environmental challenges, intensive agroforestry presents a scalable and sustainable **model** for food security, soil restoration, and agricultural intensification.

Table 3: Food Production Potential under Different Cropping Systems

System type	Production output	Source
Mono cropping	Single crop	Islam et al 2021
Traditional Agroforestry	Tree, crops, fruits, fuel wood	Rasul and Thapa, 2006
Intensive agroforestry	Homestead Gardening, Integrated Mangrove Aquaculture	Ahmed et al 2018

Conceptual Framework of Intensive Agroforestry Systems

Agroforestry is increasingly recognised as a sustainable land use approach that synergistically integrates trees and shrubs with crops and/or livestock to form ecologically resilient and economically productive landscapes (Dahal et al., 2025; Tennakoon & Tharindi, 2025). These multifunctional systems promote biodiversity, enhance soil fertility, support water conservation, and strengthen climate resilience attributes that are particularly valuable in regions vulnerable to environmental degradation and food insecurity. Agroforestry systems display considerable structural and functional diversity, ranging from simple boundary plantations and scattered onfarm trees to more complex multistory home gardens and alley cropping configurations. In tropical regions, especially South and Southeast Asia, home garden agroforestry systems are a widely adopted traditional model. These systems are typically arranged around homesteads, incorporating a variety of perennial trees, shrubs, herbaceous crops, and sometimes livestock in a vertically stratified and spatially integrated manner (Kumar, 2015).

In Bangladesh, traditional agroforestry practices such as mixed cropping, farmhouse gardening, and homestead forestry are deeply embedded in rural culture and livelihoods. These systems have long contributed to food, fuel, and fodder security while maintaining ecological balance. Contemporary efforts now aim to intensify and modernise these practices by incorporating scientific design, improved species selection, and enhanced management techniques to optimise land productivity, improve soil health, and ensure agricultural sustainability. At the core of intensive agroforestry systems lies the principle of soil health regeneration, which is fundamental to the sustainability and productivity of any agricultural system. Soil health is governed by the dynamic interaction of physical, chemical, and biological components (Rajput et al., 2024). Key indicators include the availability of essential nutrients nitrogen (N), phosphorus (P), and potassium (K) as well as pH stability, microbial biomass, resistance to erosion, and soil organic carbon (SOC). Maintaining and enhancing these indicators are critical not only for sustaining yields but also for safeguarding broader ecosystem services that underpin food security. Sal forest regions indicate that intensive agroforestry practices can significantly improve soil fertility parameters. These improvements are visually represented in Figure 4, which highlights trends in SOC build up, nutrient availability, and other soil quality markers following the adoption of intensive agroforestry interventions.

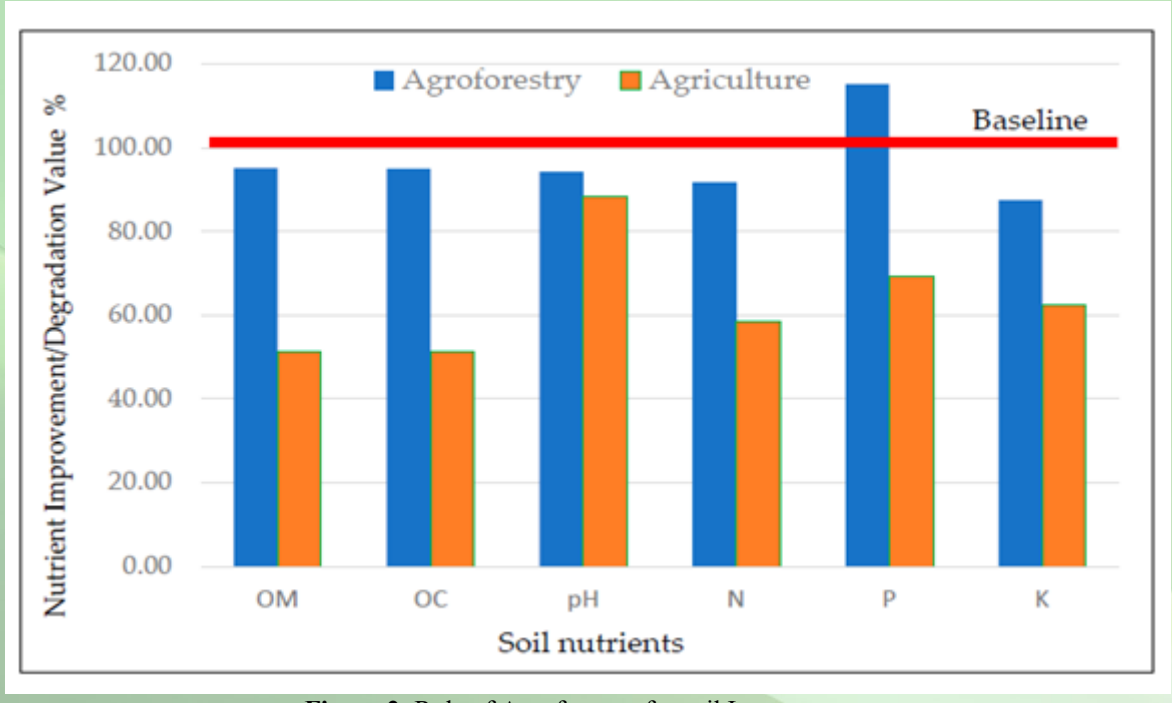


Figure 2: Role of Agroforestry for soil Improvement
Source: Islam, K.K., et al. (2024)

Intensive agroforestry systems contribute to soil enhancement through several ecological mechanisms. These include the deposition of organic matter via litter fall, biological nitrogen fixation through leguminous tree species, stimulation of soil microbial activity, and improved water retention capacity (Kaur et al., 2023). Together, these processes foster long term soil fertility, reduce vulnerability to erosion, and build resilient agro ecosystems supporting the broader transition toward sustainable and climate adaptive farming systems.

Model Success Stories and Adoption of Intensive Agroforestry Systems

Bangladesh has numerous successful agroforestry projects that have demonstrated the viability and benefits of intensive agroforestry systems (Rahman et al., 2011). In the northern districts of Rangpur and Dinajpur, farmer led innovations that integrate fruit trees with vegetables and legumes have notably enhanced both crop yields and soil stability (Chaki et al., 2023). Such combinations like maize intercropped with lentil improve nutrient cycling and reinforce soil structure, particularly in regions prone to both drought and flooding. In coastal regions such as Khulna and Barisal, mixed cropping models have been implemented that combine rice and leafy vegetables with saline tolerant trees, including mangrove species (Rahman et al., 2021). These models address soil salinity issues while enhancing food production and providing environmental services like saline intrusion control. These climate resilient strategies contribute to land rehabilitation and increased food security in ecologically vulnerable coastal areas. Similarly, in the Chittagong Hill Tracts, agroforestry combinations involving bamboo, banana, and turmeric in multistrata arrangements have yielded significant ecological and economic returns (Hossain et al., 2020). These systems well suited to steep, erosion prone terrain have reduced soil loss, enhanced land stability, and raised household incomes. Notably, these models are accessible to smallholder and indigenous communities, offering low input yet high impact solutions

Regional Background and adaptation strategies

Replicable models from neighbouring countries offer strategic insights. For instance, India's Greening India Programme has promoted drip irrigation alongside high density agroforestry (Kumar et al., 2023), while community managed agroforestry in Nepal has bolstered food security and soil retention on steep slopes (Maharjan et al., 2024). These examples underscore the importance of community engagement, cooperative marketing, and topography sensitive practices like contour planting, which could be adapted to Bangladesh's context. Modern technologies are increasingly instrumental in supporting agroforestry optimisation. The use of remote sensing, GIS based monitoring, and systems modelling allows for spatial analysis of soil variability, prediction of yields, and tracking of land use changes (Nuwarapaksha & Udumann, 2025; Toromade & Chiekezie, 2024). These tools promote evidencebased planning and strengthen the evaluation of agroforestry interventions.

Limitations and Prospects for Adoption

Several barriers hinder the widespread adoption of intensive agroforestry systems in Bangladesh, despite their promising potential. A primary limitation is the continued dependence on chemical fertilizers. When not properly integrated with biologically active systems, synthetic inputs can disrupt natural nutrient cycling and degrade soil health (Nair et al., 1999). Over application, especially when inconsistent with agroecological principles, may undermine the nutrient recycling mechanisms essential for long term sustainability. Another major challenge is the high labor intensity required for managing these systems. Unlike monoculture farming, high density and multispecies agroforestry setups demand more time, specialized skills, and technical knowledge (Raj et al., 2022). Poorly designed systems can also lead to interspecies competition for sunlight, water, and nutrients, reducing overall productivity (Ong et al., 2007). As noted by Sima and Shemelis (2025), nutrient management remains a technical obstacle, particularly in regions with limited resources and variable soil conditions. Moreover, smallholder and subsistence farmers may be reluctant to adopt agroforestry practices due to the delayed economic returns, which do not align with their immediate income needs (Rahman et al., 2017). Despite these constraints, promising strategies are emerging to overcome them. Integrated Nutrient Management (INM), which blends organic fertilizers, biofertilizers, and limited chemical inputs, has shown to significantly enhance soil health while reducing dependence on synthetic products (Prakash et al., 2024). INM approaches have been particularly effective in increasing soil organic carbon, improving pH levels, and enhancing nutrient availability in mountainous and resource scarce areas. Furthermore, agroforestry practices such as orchards, boundary plantings, homestead gardens, and multistory systems offer a range of additional ecological benefits. These include improved microclimate regulation, enhanced carbon sequestration, and greater biodiversity preservation (Kumar, 2016). Such benefits reinforce agroforestry's value as a tool for sustainable land use planning. To facilitate wider adoption, targeted extension services and farmer education programs are critical. Additionally, policy support is essential. The formal recognition of agroforestry within national land use frameworks could improve institutional backing and resource allocation, accelerating the transition toward large scale implementation.

Research Gaps and Future Directions

Although agroforestry is gaining recognition in Bangladesh, long term studies assessing its impacts on soil health, agricultural productivity, and ecosystem services remain insufficient. Most existing research is either short term or fragmented, which limits comprehensive understanding especially in the context of socioeconomic and climatic variability.To ensure meaningful adoption, future efforts must integrate regional knowledge with global scientific advancements. Lessons from countries with similar agroecological conditions should be tailored to local realities, fostering systems that enhance both livelihood security and environmental resilience. A systems based approach is vital to embed agroforestry within broader development agendas targeting poverty reduction, climate adaptation, and food security. However, key research priorities include quantifying the biophysical and economic trade offs of various agroforestry models, creating decision support tools for species and system selection, and using spatial technologies like GIS and remote sensing to inform land use planning. Moreover, policy frameworks must institutionalize agroforestry within national strategies for climate resilience and sustainable agriculture. With adequate policy backing, research investment, and extension infrastructure, agroforestry in Bangladesh has the potential to evolve from a soil rehabilitation technique into a driver of sustainable development and equitable rural transformation.

Conclusion

This review highlights the transformative potential of intensive agroforestry systems in enhancing Bangladesh's food security, soil health, and climate resilience. By integrating trees with crops in strategic and ecologically sensitive ways, these systems offer a viable alternative to conventional monoculture farming, particularly in land constrained and environmentally vulnerable regions. Case studies at both national and regional levels illustrate that well designed agroforestry systems can enhance biodiversity, boost soil fertility, and increase overall agricultural output. Nevertheless, challenges such as labor intensity, insufficient technical support, and the lack of long term studies continue to hamper broader adoption. Looking ahead, scaling up agroforestry will require a coordinated approach that blends scientific innovation, farmer education, supportive policy frameworks, and modern technological tools. Only through such an integrated effort can agroforestry fulfil its promise as a cornerstone of sustainable agriculture and rural development in Bangladesh.

Novelty of the Present Review

This review uniquely focuses on high density, multispecies agroforestry systems, distinguishing them from traditional models by highlighting their enhanced ecological and agronomic functions. It explicitly explores the link between soil health improvement and tangible food production benefits for smallholder farmers. Grounded in evidence from the Bangladeshi context, the review addresses a critical gap in localized assessments of intensive agroforestry. It underscores agroforestry as a comprehensive, systems based strategy that integrates agroecological principles with food security and climate resilience, offering a pathway toward sustainable rural livelihoods.

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Hydrogen Farming

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Abstract

Molecular hydrogen, a gas that is abundantly present in the atmosphere, is light, colorless, odorless, and non-toxic. Its ability to rapidly penetrate tissues, along with its antioxidant, anti-inflammatory, and gene-regulatory biological effects, has been predominantly applied in the medical field. These biological effects of hydrogen may also yield beneficial outcomes in agricultural practices. The agricultural sector faces numerous challenges, including population growth, air pollution, climate change, and declining soil fertility. Hydrogen's reducibility, as well as its characteristics as a plant growth regulator, and its safe, environmentally friendly, and sustainable properties, make it a promising approach for both addressing these challenges and advancing agricultural development. Hydrogen farming refers to the application of hydrogen biology in agriculture. Hydrogen-rich water (HRW) treatments can regulate plant hormones, enhance resistance to stress conditions, support growth and development, increase nutritional value, and influence protein modifications through the regulation of mRNA and DNA expression. Furthermore, it may help reduce nitrite accumulation during storage, thus contributing to food safety. This study aims to investigate the effects of hydrogen farming by reviewing research involving hydrogen-rich water (HRW) applied to various pre-harvest vegetables and fruits.

Keywords: *Hydrogen; plants; Agriculture; Quality characteristics*

Hidrojen Tarımcılığı

Özet

Havada yaygın olarak bulunan moleküler hidrojen hafif, renksiz, kokusuz ve toksik olmayan bir gazdır. Dokulara hızlı nüfuz etmesi, antioksidan, anti-inflamatuar ve gen düzenleyici gibi biyolojik etkileriyle daha çok tıp alanındaki uygulamalarla karşımıza çıkmaktadır. Hidrojenin bu biyolojik etkileri tarım alanında da olumlu sonuçlar sağlayabilir. Tarım sektörü, nüfus artışı, hava kirliliği, iklimsel faktörler, toprak verimliliğinin azalması gibi birçok sorunla karşı karşıyadır. Hidrojenin İndirgenebilme özelliği, bitki büyüme düzenleyicisi, güvenli, yeşil ve çevre dostu olma gibi özellikleriyle, tarım alanında hem bu sorunların çözümü hem de tarımın gelişmesi için iyi bir uygulama alanı olabilir. Hidrojen tarımı, hidrojen biyolojisinin tarıma uygulanmasıdır. Hidrojen açısından zengin su (HRW) uygulamaları, bitki hormonlarını düzenleyerek; bitkilerin stres koşullarına karşı direncini artırabilir, büyüme ve gelişmesini destekleyebilir, besin değerini artırabilir, mRNA ve DNA ekspresyonunu düzenleyerek protein modifikasyonunu etkileyebilir. Aynı zamanda depolama sırasında nitrit birikimini azaltarak gıda güvenliğinin korunmasına yardımcı olabilir. Bu çalışma, hidrojen tarımının etkilerini araştırmak için hasat öncesi bazı sebze ve meyveler üzerinde hidrojen açısından zengin su (HRW) ile yapılan bazı araştırmaları ele almayı amaçlamaktadır.

Anahtar kelime*: Hidrojen; Bitki; Tarım; Kalite özellikleri*

Giriş

Hidrojen gazı evrende en çok bulunan elementtir (Alwazeer et al., 2021; Wen-biao Shen et al., 2018). Hidrojen, başka bir hidrojen atomu ile birleşerek kimyasal formülü H_2 olan moleküler hidrojeni oluşturur. Moleküler hidrojen, standart sıcaklık ve basınçta (STP) 0,08988 g/L yoğunluğa sahip (Alwazeer et al., 2021) renksiz, kokusuz, tatsız, metalik olmayan (Alwazeer & Çiçek, 2022) en küçük ve en hafif moleküldür (Alwazeer et al., 2021). Düşük yoğunluk ve boyut ile yüksek ayrışma enerjisine sahip olması nedeniyle gıdalarda ve çevrede kalıntı bırakmaz ve toksik değildir (Alwazeer, Elnasanelkasim, Çiçek, et al., 2023)(Alwazeer, Elnasanelkasim, Engin, et al., 2023). Moleküler hidrojen (H_2) sıfır karbon emisyonu, yüksek enerji değeri nedeniyle son yıllarda potansiyel enerji kaynağı olarak değerlendirilmektedir. Hayvanlar üzerinde H_2 gazıyla yapılan laboratuvar çalışmalarında, H_2 gazının biyolojik etkileri aşamalı olarak keşfedilmiştir (Liu et al., 2024). Ohsawa ve ark. (2007), sıçanların %2-4 (h/h) H_2 solunması sonrasında iskemik beyin hasarında iyileşmeler gözlemlemesiyle, H_2 gazının klinik uygulamalardaki potansiyeli fark edilmiştir (L. Li et al., 2022a). H_2 gazının etkili sitoprotektif ajan, antioksidan

(Russell et al., 2024), çeşitli gen ifadelerini düzenleyerek, antiapoptik, anti-inflamatuar ve anti-alerjik etkiler gösteren bir terapi gazı olduğu ortaya konmuştur (Liu et al., 2024)(Alwazeer & Çiçek, 2022)(Bulut et al., 2023) .Yüksek difüzyon hızına sahip moleküler hidrojen (H_2) biyolojik doku ve hücrelere hızlı bir şekilde yayılıp, hücre zarına kolaylıkla nüfuz etmektedir. Aynı zamanda vücudun redoks reaksiyonlarını değiştirmeyerek, hiçbir yan etkiye sahip değildir. Moleküler hidrojenin biyolojik ve tıbbi etkileri üzerine birçok çalışma yapılmakla birlikte bu araştırmalar devam etmektedir (Alwazeer & Çiçek, 2022). Bu çalışmalarla, moleküler hidrojen (H_2), metabolik, sindirim, solunum ve kardiyovasküler hastalıklar, nörodejeneratif bozukluklar ve kanser gibi hastalıkların tedavisi için umut verici olmaktadır (L. Li et al., 2022b; M. Li et al., 2024).

Hidrojen biyolojisinin etkileri tıp alanında olduğu gibi tarım alanında da olumlu sonuçlar sağlayabilir. Tarım, iklim değişikliği, doğal afetler, çevre kirliliği ve gıda güvenliği sorunlarının sebep olduğu birçok problemle karşı karşıyadır (L. Li, Lou, et al., 2021). Kimyasal kirlilik, biyolojik çeşitliliğin azalması gibi çağdaş sorunlar, kaliteli gıdaların üretilmesini, korunmasını ve dağıtımını giderek zorlaştırmaktadır (Russell et al., 2024).

Hidrojen tarımı, bu zorlukların çözümüne katkı sağlayacak hidrojen biyolojisinin pratik bir uygulamasıdır (L. Li, Lou, et al., 2021). Yapılan çalışmalar, moleküler hidrojenin (H_2) bazı botanik etkilere sahip olduğunu göstermiştir. Moleküler ağı, miRNA ve gen ekspresyonunun, hormon düzeylerinin kontrolü ve protein modifikasyonlarının düzenlenmesi süreçlerini kapsar (Wen-biao Shen et al., 2018). Bitkilerde, çevresel zorluklar, doğal bozulma ve oksidatif strese bağlı hücresel ve doku hasarı gibi faktörler gıdanın büyümesini, verimini ve kalitesini olumsuz etkileyebilir. Oksidatif hasar, gıdada lipit oksidasyonuna, renk bozulmasına ve lezzet değişimlerine neden olabilir (Dong et al., 2023). Buna karşılık moleküler hidrojen (H_2), bitkinin oksidatif strese karşı toleransını artırabilir, bitki büyüme ve gelişimini destekleyebilir (M. Li et al., 2024), besin değerini artırabilir, raf ömrünü uzatabilir ve sebzelerin depolanması sırasında nitrit birikimini azaltabilir (L. Li, Lou, et al., 2021). Son yıllarda moleküler hidrojen (H_2) çalışmaları bitkilere doğru kaymıştır (L. Li et al., 2022) ve birçok akademik çalışmada, bitkilerin ekilme ve büyüme evrelerinde H_2 'ye maruz bırakılması sonucunda bitki kök oluşumunun iyileştiği, bitkinin hastalık direncinin arttığı ve tohum, yaprak, meyve büyüme ve gelişmesini desteklediği gözlemlenmiştir (Russell et al., 2024). Bitki köklerindeki iyileşmenin, kök iyileşmesini destekleyen kök bakterilerinin çoğalmasıyla ilişkili olup (Alwazeer et al., 2024a); bu da kimyasal gübrelere karşılık H_2 'nin alternatif bir gübre olma potansiyeline ortaya koymuştur (L. Li et al., 2022),(Alwazeer et al., 2024b). Bu sonuçlara göre H_2'nin tarım alanı uygulamaları, tarımsal faydalar açısından önemli bir rolü olabilir (L. Li, Zeng, et al., 2021).

Hidrojen Açısından Zengin Su (HRW) Uygulamaları

Gaz formundaki moleküler hidrojen H_2, ayrışma hızının yüksek olması ve yüksek konsantrasyonlarda yanıcı özelliği saha uygulaması için pratik değildir (M. Li et al., 2024). Bu yüzden moleküler hidrojen (H_2) açısından zengin su (HRW) daha uygulanabilir alternatiftir. HRW uygulamalarında, turp filizleri ve yonca fidelerinin antosiyaninler ve flovonoidler gibi ikincil metobolitleri ile filizlenmiş arpanın besin bileşiklerini artırdığı gözlemlenmiştir. Pirinç ile yapılan başka bir çalışmada ise verim ve kalitesinin arttığı gözlemlenmiştir (Liu et al., 2024). (H_2) açısından zengin su (HRW), salatalık (*Cucumis sativus*) ve domates (*Lycopersicon esculentum*) bitkilerinin kök gelişimini teşvik ettiği gözlemlenirken, yoncada (*Medicago sativa*) ağır metal toksisitesinin hafiflediği keşfedilmiştir (L. Li, Zeng, et al., 2021).

Farklı bitki türlerinde HRW'nin etkileri üzerine yapılan bazı araştırmaların analizi

Çin lahanası (*Brassica chinensis* L. 'Qingshan') hem verimi hemde kalitesi üzerine yapılan araştırmada, Çin lahanası, hidrojen nanokabarcık suyu (HNW) formunda olan hidrojen bazlı sulama ile sulanmıştır. Hidrojen bazlı sulama, Çin lahanasının büyüme ve verimle ilgili sonuçlarını belirgin şekilde iyileştirirken, besin kalitesini artırıp nitrat içeriğini azaltmıştır. Denemeler sonrası hidrojen bazlı sulama ile kontrol grupları karşılaştırıldığında, hidrojen bazlı sulama ile elde edilen Çin lahanasının şeker oranı, çözünür protein oranı ve klorofil oranı önemli ölçüde artmıştır. Sonraki denemelerde, HNW demir (Fe), çinko (Zn) ve bakır (Cu) gibi eser elementlerin yanı sıra fosfor (P), potasyum (K) ve magnezyum (Mg) gibi makro elementlerin içeriklerinin karşılaştırılmasını sağlanmıştır. Fe, Zn ve Cu içerikleri önemli ölçüde artarken; K ve Mg içeriklerindeki önemsiz değişikler karşısında P içeriği önemli ölçüde artmıştır. HNW ile antioksidan bileşiklerinin ve antioksidan aktivitesinin arttığı gözlemlenmiştir. Aynı zamanda hidrojen bazlı sulamanın, Askorbik asit (AsA) içeriğini önemli ölçüde artırdığı tespit edilirken buna PMM1 (fosfomannomutaz), GMP2 (GDPR-mannoz pirofosforilaz), GME1 (GDPR-mannoz-3',5'-epimeraz), GGP3 (GDPR -l -galaktoz fosforilaz), GPP (l -galaktoz-1-fosfat fosfatazı) ve MDHAR2 (monodehidroaskorbat redüktaz dahil olmak üzere AsA biyosenteziyle ilişkili genlerin önemli ölçüde yukarı düzenlenmesinin eşlik ettiği gözlemlenmiştir (Liu et al., 2024). Pirinç ile yapılan başka bir çalışmada, HNW ile yapılan sulamanın, pirincin tarla ve tane kalite özelliklerini etkileyip etkilemediği incelenmiştir. Elde edilen verilere göre HNW ile sulanan pirinçlerin uzunluk, genişlik ve kalınlık farkının belirgin olduğu görülmüştür. Pirinç bitkilerinde azot (N), fosfor (P) ve potasyum (K) emilimiyle ilgili temsili genlerin transkriptlerinin, N asimilasyonu

ve taşınmasının yanı sıra P ve K emiliminin kontrolü de dahil olmak üzere Nitrat taşıyıcıları 2.3 (NRT2.3), Nitrit redüktaz (NiR), ABC1 baskılayıcı 1 (ARE1), Nin benzeri protein 4 (NLP4) ve Potasyum taşıyıcısı 1 (AKT1), HNW ile sulanan pirinç köklerinde belirgin şekilde arttığı görülmüştür. Beyaz pirincin HNW'nin jel kıvamını arttığı, pirincin tebeşirlilik oranını azalttığı keşfedilmiştir. Sonraki sonuçlar, HNW sulama işleminin, pirincin endospermindeki önemli ve ana depolama proteini olan glutelinde önemli değişiklik olmadan toplam protein seviyesini %19,8 oranında; toplam nişasta içeriğini değiştirmeden amiloz içeriğini %31,6 oranında azalttığı görülmüştür. Bu bulguların mekanizmasını araştırmak için, beyaz pirinçteki amiloz oluşumunu kontrol eden ilgili bazı genler, granüle bağlı nişasta sentaz1 (GBSS1), nişasta izomeraz1 (ISA1) ve nişasta dallanma enzimi1 / 2 (SBE1 / 2) dahil olmak üzere analizler yapılmış ve hedef genlerin transkripsiyonel ifadesindeki değişiklikler, amiloz içeriğindeki azalmayla ilişkili olduğu saptanmıştır. HNW ile sulamanın beyaz pirinç element içeriği ile ilişkisini saptamak için daha fazla çalışma yapılmıştır. Yapılan deneyler sonucunda Cd (kadminyum) ve Sn (kalay) içeriklerinde önemli azalma görülmüştür. HNW'nin beyaz pirinçteki P (fosfor), K (potasyum), Mg (magnezyum) ve Fe (demir) dahil birçok besin elementinin içeriğini artırdığı tespit edilmiştir (Cheng et al., 2021). Çilek meyvesi ile yapılan (Fragaria × ananassa 'Benihoppe') bir çalışmada, çileklerin tarlaya ekiminden hemen sonra HNW'li su uygulanmaya başlanmıştır. Hasat sonrası çileklerde, çilek meyvesinin lezzetini artırmakla beraber en önemlisi de lignin, selüloz ve hemiselüloz sentezini düzenleyerek çilek meyvesinin raf ömrünü olumlu yönde etkilediği keşfedilmiştir (Jin et al., 2023). Çilek meyvesi ile yapılan başka bir çalışmada ise HNW uygulaması aldehitler, ketonlar, esterler ve asitler gibi toplam uçucu bileşiklerin konsantrasyonlarını farklı şekilde artırdığı gözlemlenmiştir. HNW uygulaması çilekteki çözünür şeker (glukoz, sakaroz, fruktoz) miktarını artırarak, meyvedeki şeker-asit oranı değişmiştir. Bu durumunun ise tüketici beğenisini olumlu yönde etkileyeceği vurgulanmıştır (L. Li et al., 2022).

Sonuç

Doğal afetler, çevre kirliliği, hızlı nüfus artışı gibi birçok faktör tarım sektörünü olumsuz etkilemekte; tarımsal üretimde azalmaya ve kalite problemlerine sebep olmaktadır. Sağlık, enerji alanlarında olduğu gibi Moleküler hidrojen (H_2), tarım alanında da yeşil bir çözüm olabilir (Alwazeer et al., 2024a). Son yıllarda yapılan araştırmalar incelendiğinde, hidrojen tarımı, bu yaklaşım için umut verici olmuştur. Daha fazla araştırma ve geliştirme çalışmalarıyla hidrojen tarımı, güvenli, lezzetli, sağlıklı ve yüksek verimli tarım ürünleri sağlamayı destekleyebilir (L. Li, Lou, et al., 2021).

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Using of Probiotics and Growth Promoters in Sea Bream (*Sparus aurata*, L.) Larval Culture: Combined Effects on Growth Performance and Morphological Development

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Abstract

Nowadays, aquaculture sector is one of the fastest developing sectors in the food industry. Increasing production quantities and changing climatic conditions cause some problems. In this sense, in the recent years, in addition to probiotics, the use of some additives and growth promoters are commonly used in the aquaculture sector. In this study, the combined effects of feeding probiotics (*Bacillus* sp.) and growth promoters (Viusid®) supplemented to the feed under culture conditions on growth parameters and morphological development of sea bream (*Sparus aurata*) larvae, which are intensively produced in our country, were investigated. For this purpose, within the scope of the experiments lasting between 0-40 days after hatching, in the study designed with 4 different experimental groups and 3 replicates, the experimental group in which no supplementation was made was accepted as the control group (C), and probiotic (P), growth promoter (V) and probiotic+growth promoter (P+V) were applied in the other 3 experimental groups, respectively. When the data obtained at the end of the experiment were analysed, the best growth performance and survival rate were observed in P+V group, followed by V, P and C groups, and C group showed significant differences with the other experimental groups ($p<0,05$). Similarly, when the deformation rates were analysed, the highest deformation rate was found in the C group and significant differences were found with the other experimental groups (P+V, V and P) ($p<0,05$). In conclusion, although probiotic and growth promoters provided significant increases in growth performance, survival rate and morphological aspects when used separately, it was determined that the combined effects gave better results on these parameters when used together.

Key Words: *Sea bream, Sparus aurata, Probiotics, Growth promoters, Growth performance.*

Çipura (*Sparus aurata*, L.) Larva Kültüründe Probiyotik ve Büyüme Hızlandırıcıların Kullanımı: Büyüme Performansı ve Morfolojik Gelişim Üzerine Bileşik Etkisi

Özet

Günümüzde akuakültür sektörü gıda endüstrisi içinde en hızlı gelişen sektörlerin başında gelmektedir. Artan üretim miktarları ve değişen iklim koşulları beraberinde bazı sorunlara da neden olmaktadır. Bu bağlamda son yıllarda probiyotiklerin yanında bazı katkı maddelerinin ve büyüme hızlandırıcıların akuakültür sektöründeki kullanımları yaygın hale gelmiştir. Bu çalışmada, ülkemizde yoğun olarak üretimi yapılan çipura (*Sparus aurata*) larvalarının kültür koşullarında yemlere eklenen probiyotik (*Bacillus* sp.) ve büyüme hızlandırıcılar (Viusid®) ile beslenmesinin büyüme parametrelerinin yanında ve morfolojik gelişim üzerine bileşik etkileri incelenmiştir. Bu amaçla 0-40. günler arasında süren denemeler kapsamında 4 farklı deneme grubu ve 3 tekrarlı olarak tasarlanan çalışmada herhangi bir uygulamanın yapılmadığı deneme grubu kontrol grubu (C) olarak kabul edilmiş, diğer 3 deneme grubunda ise sırasıyla probiyotik (P), büyüme hızlandırıcı (V) ve probiyotik+büyüme hızlandırıcı (P+V) uygulanmıştır. Deneme sonunda elde edilen veriler değerlendirildiğinde en iyi büyüme performansı ve yaşama oranı P+V grubunda gözlenirken bu grubu V, P ve C grubu izlemiş, C grubu diğer deneme grupları ile farklılık göstermiştir ($p<0,05$). Benzer şekilde, defromasyon oranları incelendiğinde de en yüksek deformasyon oranı C grubunda tespit edilmiş ve diğer deneme grupları (P+V, V ve P) ile önemli farklılılar bulunmuştur ($p<0,05$). Sonuç olarak probiyotik ve büyüme hızlandırıcılar ayrı ayrı kullanıldıklarında büyüme performansı, yaşama oranı ve morfolojik açıdan önemli artışlar sağlasa da birlikte kullanıldığında bileşik etkisinin bu paratmereler üzerinde daha iyi sonuçlar verdiği tespit edilmiştir.

Anahtar Kelimeler: *Çipura, Sparus aurata, Probiyotik, Büyüme hızlandırıcı, Büyüme performansı.*

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Fenolik Bileşikler ile Mineraller Arasındaki Etkileşim Mekanizmaları Ve Besinsel Etkileri

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Özet

Fenolik bileşikler, bitkisel kaynaklarda yaygın olarak bulunan ve insan sağlığı üzerinde çeşitli olumlu etkiler gösteren biyoaktif bileşiklerdir. Antioksidan, antiinflamatuvar ve antimikrobiyal özellikleri sayesinde fenolik bileşikler, kronik hastalıkların önlenmesi ve genel sağlık durumunun iyileştirilmesi açısından büyük önem taşımaktadır. Ancak bu bileşiklerin vücutta nasıl kullanıldığı, yani biyoyararlanımı, çeşitli faktörlerden etkilenmektedir. Bu faktörlerden biri de fenolik bileşiklerin minerallerle olan etkileşimidir. Fenolik bileşikler, başta demir, çinko ve kalsiyum olmak üzere çeşitli minerallerle kompleksler oluşturarak mineral emilimini artırabilir veya engelleyebilir. Örneğin, fenolik bileşiklerin demir ile şelat oluşturma yeteneği nedeniyle, bitkisel gıdalardaki non-hem demirin biyoyararlanımı önemli ölçüde azalabilir. Bu durum özellikle demir eksikliği riski taşıyan bireyler açısından önemlidir. Benzer şekilde, çinko ile fenolik bileşiklerin etkileşimi sonucunda çözünmeyen kompleksler oluşabilir ve çinko emilimi engellenebilir. Kalsiyum ise fenolik bileşiklerle çözünmeyen tuzlar oluşturabilir, bu da kalsiyumun biyoyararlanımını düşürebilir. Ancak bu etkileşimlerin her zaman olumsuz olmadığı da bilinmektedir. Örneğin, bazı fenolik bileşiklerin minerallerle etkileşimi sonucu, mineral emilimini artıran çözünebilir kompleksler oluşabilir. Ayrıca, fenolik bileşiklerin antioksidan özellikleri sayesinde oksidatif stresin azaltılması, mineral metabolizmasını dolaylı olarak destekleyebilir. Örneğin, polifenollerin demirin serbest radikal üretimini engelleyerek vücutta demir dengesini korumaya yardımcı olabileceği gösterilmiştir. Beslenme açısından değerlendirildiğinde, fenolik bileşikler ve mineraller arasındaki bu etkileşimler, özellikle bitkisel bazlı diyetler açısından önem arz etmektedir. Fenolik bileşiklerin aşırı alımı, bazı minerallerin emilimini azaltarak eksiklik riskini artırabilirken, dengeli bir beslenme planı ile bu etkileşimlerin olumsuz etkileri en aza indirilebilir. Bu nedenle, minerallerin optimal emilimini sağlamak için fenolik bileşiklerden zengin gıdalarla mineral kaynaklarının birlikte tüketim zamanlaması dikkatle planlanmalıdır. Örneğin, çay ve kahve gibi polifenol içeriği yüksek içeceklerin demir açısından zengin öğünlerle birlikte tüketimi sınırlanmalı, C vitamini gibi emilimi artırıcı faktörlerle desteklenmelidir. Bu çalışma, fenolik bileşikler ve mineraller arasındaki etkileşim mekanizmalarını inceleyerek, bu etkileşimlerin beslenme üzerindeki etkilerini değerlendirmektedir. Elde edilen bulgular, beslenme stratejilerinin daha bilinçli bir şekilde planlanması gerektiğini ortaya koymakta ve bu etkileşimlerin sağlık üzerindeki uzun vadeli etkilerine yönelik daha fazla araştırmaya ihtiyaç olduğunu vurgulamaktadır.

***Anahtar kelimeler**: Fenolik bileşikler; Mineraller; Biyoyararlanım; Beslenme*

Interaction Mechanisms And Nutritional Effects Between Phenolic Compounds And Minerals

Abstract

Phenolic compounds are bioactive compounds that are widely found in plant sources and have various positive effects on human health. Thanks to their antioxidant, anti-inflammatory, and antimicrobial properties, phenolic compounds are important in preventing chronic diseases and improving general health. However, how these compounds are used in the body, i.e., their bioavailability, is affected by various factors. One of these factors is the interaction of phenolic compounds with minerals. Phenolic compounds can increase or inhibit mineral absorption by forming complexes with various minerals, especially iron, zinc, and calcium. For example, due to the ability of phenolic compounds to chelate with iron, the bioavailability of non-heme iron in plant foods can be significantly reduced. This is especially important for individuals at risk of iron deficiency. Similarly, insoluble complexes can form due to the interaction of zinc with phenolic compounds, and zinc absorption can be inhibited. Calcium can form insoluble salts with phenolic compounds, which can reduce the bioavailability of calcium. However, it is also known that these interactions are not always negative. For example, due to the interaction of some phenolic compounds with minerals, soluble complexes that increase mineral absorption can be formed. In addition, the reduction of oxidative stress, thanks to the antioxidant properties of phenolic compounds, can indirectly support mineral metabolism. For example, it has been shown that polyphenols can help maintain iron balance in the body by preventing the free radical production of iron. When evaluated in terms of nutrition, these interactions between phenolic compounds and minerals are especially important for plant-based diets. While

excessive intake of phenolic compounds can reduce the absorption of some minerals and increase the risk of deficiency, the negative effects of these interactions can be minimized with a balanced nutrition plan. Therefore, the timing of consuming mineral sources and foods rich in phenolic compounds should be carefully planned to ensure optimal absorption of minerals. For example, the consumption of polyphenol-rich beverages such as tea and coffee should be limited to iron-rich meals and should be supported by absorption-enhancing factors such as vitamin C. This study examines the interaction mechanisms between phenolic compounds and minerals and evaluates the effects of these interactions on nutrition. The findings reveal that nutritional strategies should be planned more consciously and emphasize the need for more research on the long-term effects of these interactions on health.

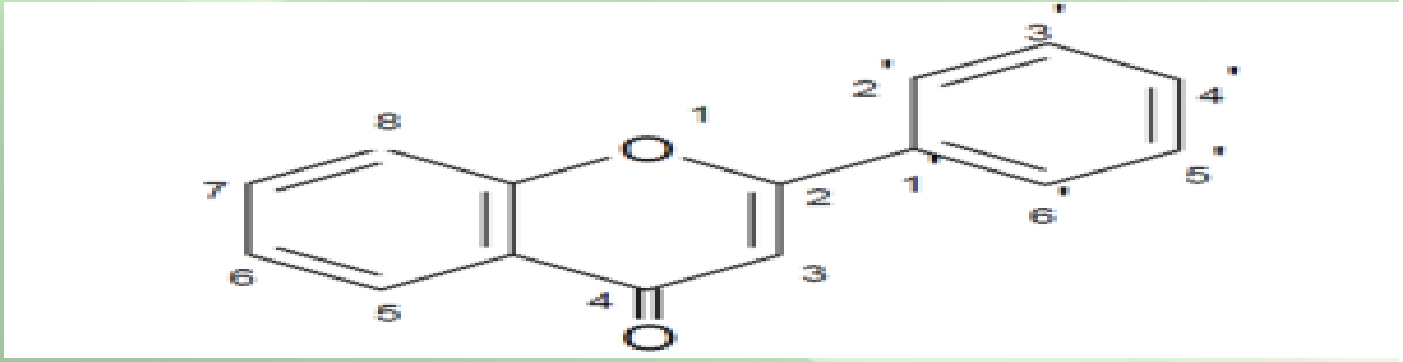
Keywords: *Phenolic compounds; Minerals; Bioavailability; Nutrition*

1. Giriş

Fenolik bileşikler, bitkisel kaynaklı gıdalarda yaygın olarak bulunan, biyolojik olarak aktif olan ve çeşitli sağlık yararları ile ilişkilendirilen bileşiklerdir. Fenolik bileşikler, özellikle antioksidan, anti-inflamatuvar, antimikrobiyal, antikanserojen ve kardiyovasküler sağlık üzerinde koruyucu etkiler göstermesiyle tanınmaktadır (Scalbert vd., 2005). Bu bileşikler, bitkilerde genellikle sekonder metabolitler olarak bulunurlar ve besinlerde genellikle flavonoidler, fenolik asitler, lignanlar, stilbenler gibi sınıflarda yer alırlar. Fenolik bileşiklerin sağlık üzerine olan etkileri, biyoyararlanımları ve vücutta nasıl metabolize oldukları ile doğrudan ilişkilidir. Bununla birlikte, fenolik bileşiklerin biyoyararlanımı ve vücutta gösterdikleri biyolojik aktiviteler, vücutta bulunan diğer besin bileşenleri ve minerallerle olan etkileşimleriyle şekillenir. Bu etkileşimler, beslenme ve sağlık üzerine etkilerini belirleyebilir. Fenolik bileşikler, mineraller ile etkileşime girerek, bu minerallerin emilimini, biyoyararlanımını ve vücutta ne şekilde kullanıldığını değiştirebilir. Mineraller, vücudun düzgün çalışabilmesi için kritik öneme sahip olup, kemik sağlığı, bağışıklık sistemi, enzim aktivasyonları ve elektrolit dengesinin sağlanması gibi birçok biyolojik fonksiyonu yerine getirirler. Demir, çinko, kalsiyum, magnezyum gibi minerallerin vücutta yeterli seviyede bulunması, optimal sağlık için gereklidir. Bununla birlikte, fenolik bileşiklerin bu minerallerle olan etkileşimleri, mineral emiliminde ve biyoyararlanımında olumlu ya da olumsuz değişikliklere yol açabilir (Shahidi & Peng, 2018). Özellikle, fenolik bileşikler genellikle minerallerle çözünmeyen kompleksler oluşturarak, bu minerallerin emilimini engelleyebilirler. Örneğin, çayda bulunan tanenler veya baklagillerdeki fitatlar, demir ve çinko gibi minerallerle bağlanarak, bu minerallerin biyoyararlanımını önemli ölçüde azaltabilirler. Bununla birlikte, bazı fenolik bileşiklerin antioksidan özellikleri ve minerallerle etkileşimleri, serbest radikallerin ve oksidatif stresin azaltılmasında faydalı olabilir. Fenolik bileşiklerin bu etkileşimleri, yalnızca minerallerin biyoyararlanımını etkilemekle kalmaz, aynı zamanda genel vücut fonksiyonlarını da modüle edebilir (Emirhüseyinoğlu vd., 2025). Bu derleme, fenolik bileşiklerin minerallerle olan etkileşimlerini incelemeyi amaçlamaktadır. Demir, çinko, kalsiyum, magnezyum ve diğer mineraller ile fenolik bileşiklerin etkileşim mekanizmaları ve bu etkileşimlerin besinsel etkileri üzerinde durulacaktır. Ayrıca, fenolik bileşiklerin bu minerallerle olan etkileşimlerinin sağlık üzerine olan etkileri tartışılacak ve uygun beslenme stratejileri ile bu etkileşimlerin nasıl yönetilebileceği üzerine önerilerde bulunulacaktır.

2. Fenolik Bileşiklerin Genel Özellikleri

Fenolik bileşikler, bitkilerde bulunan ve biyolojik olarak aktif olan organik bileşiklerdir. Bu bileşiklerin yapısal özellikleri genellikle bir veya daha fazla fenol grubu içeren bir karbon halkasından oluşur (Şekil 1). Fenolik bileşikler, bitkilerin metabolik süreçlerinde önemli bir rol oynar ve bitkiler için savunma mekanizmaları, renk, tat ve aroma gibi özellikler sağlar. İnsan sağlığı açısından fenolik bileşikler, antioksidan, antimikrobiyal, anti-inflamatuvar ve anti-kanserojenik etkiler gibi çok çeşitli biyolojik etkilere sahiptir (Karabulut & Yemiş, 2019).



Şekil 1. Flavonoidlerin kimyasal yapısı

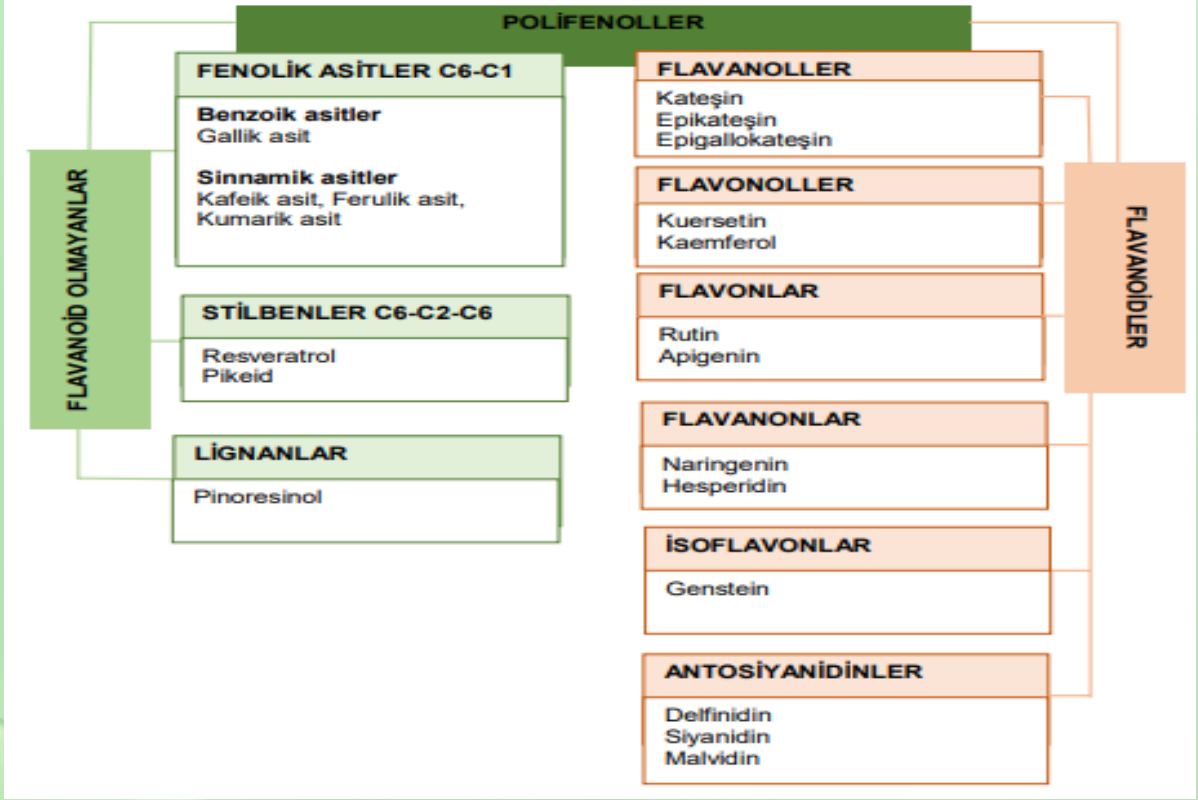
Fenolik bileşikler, bitkisel kaynaklardan elde edilen gıdalarda yaygın olarak bulunur ve bu gıdaların besinsel değerini artırabilir. Çoğu fenolik bileşik, bitkilerde sekonder metabolitler olarak sentezlenir, bu da onların doğrudan bitkilerin büyümesi için gerekli olmayan, ancak organizmanın çevresel streslere karşı savunmasına yardımcı olan bileşikler oldukları anlamına gelir. Fenolik bileşiklerin kimyasal yapıları oldukça çeşitlidir ve başlıca sınıfları şunlardır (Şekil 2):

2.1. Fenolik Asitler: Bunlar, fenol halkasına bağlı bir karboksil grubuna sahip bileşiklerdir ve en yaygın olarak bulunan fenolik bileşik sınıfıdır. Örnekler arasında gallik asit, ferulik asit, kafeik asit ve klorojenik asit yer alır.

2.2. Flavonoidler: Flavonoidler, genellikle 15 karbon atomu içeren ve iki fenol halkası ile bağlanan bir yapıya sahip bileşiklerdir. Bu sınıf, antosiyaninler, kateşinler, kuersetin, epikateşin, ve luteolin gibi birçok bileşiği içerir. Flavonoidler, genellikle meyve ve sebzelerde bulunur ve sağlık üzerinde olumlu etkiler gösterir.

2.3. Lignanlar: Lignanlar, bitkilerde bulunan, bir fenolik yapıyı içerip ayrıca karbon-karbon bağlarıyla birbirine bağlı aromatik halkalar oluşturan bileşiklerdir. Lignanlar, özellikle tohumlar, tam tahıllar ve sebzelerde bulunur ve antioksidan özellikler gösterirler.

2.4. Stilbenler: Stilbenler, resveratrol gibi bileşikleri içeren, genellikle üzüm kabuğu, kırmızı şarap ve bazı meyvelerde bulunan bir fenolik bileşik sınıfıdır. Stilbenler, kanserle savaşma ve kalp sağlığını destekleme özellikleriyle tanınır.



Şekil 2. Fenolik bileşiklerin sınıflandırılması (Karabulut & Yemiş, 2019)

Fenolik bileşiklerin vücuda alınması sonrasında, birçok biyolojik etkiye sahip olmaları nedeniyle sağlık üzerinde çeşitli yararlar sağlar. Bu yararlar, büyük ölçüde onların antioksidan kapasitesi ile ilişkilidir. Antioksidan etkiler, serbest radikallerin nötralize edilmesine yardımcı olur, böylece oksidatif stresin önüne geçilerek hücresel hasar engellenir. Bunun yanı sıra, fenolik bileşiklerin anti-inflamatuvar ve antimikrobiyal etkileri de bulunmaktadır, bu da onların bağışıklık sistemini destekleyerek çeşitli hastalıklara karşı koruyucu bir rol oynamasını sağlar.

3. Fenolik Bileşikler ve Mineraller Arasındaki Etkileşim Mekanizmaları

Fenolik bileşikler, bitkisel kaynaklı gıdalarda bulunan, kimyasal olarak fenol halkaları içeren ve biyolojik açıdan oldukça aktif olan organik bileşiklerdir. Bu bileşiklerin başlıca sınıfları flavonoidler, fenolik asitler, stilbenler ve lignanlar gibi gruplarda toplanmaktadır. Fenolik bileşiklerin sağlık üzerindeki olumlu etkileri uzun yıllardır araştırılmaktadır ve bu etkiler büyük oranda onların antioksidan, antimikrobiyal, anti-inflamatuvar ve kardiyovasküler hastalıklarla mücadele etme potansiyellerine dayanmaktadır. Ancak, bu bileşiklerin beslenme ve metabolizma üzerindeki etkileri, yalnızca biyolojik aktiviteleri ile sınırlı değildir; fenolik bileşikler aynı zamanda vücutta bulunan minerallerle etkileşime girerek bu minerallerin biyoyararlanımını ve metabolik etkinliğini

etkileyebilirler. Mineraller, vücudun temel fonksiyonlarını düzenleyen mikronutrientlerdir (Eylem Atak & Mehmet Emin Uslu, 2018). Özellikle demir, çinko, kalsiyum ve magnezyum gibi mineraller, vücutta enzim fonksiyonları, kemik sağlığı, bağışıklık yanıtları ve oksijen taşınımı gibi kritik süreçlerin düzenlenmesinde rol oynar. Bununla birlikte, fenolik bileşiklerin bu minerallerle olan etkileşimleri, özellikle mineral emiliminde ve biyoyararlanımında önemli değişikliklere yol açabilir. Fenolik bileşiklerin, minerallerle etkileşimlerinin genellikle çözünmeyen kompleksler oluşturarak minerallerin biyoyararlanımını sınırladığı bilinmektedir.

3.1. Demir ile Etkileşim

Demir, vücutta oksijen taşıma fonksiyonu gibi birçok önemli biyolojik süreçte yer alan bir mineraldir. Demir, hem ve non-hem olmak üzere iki ana formda bulunur. Hem demir, hayvansal kaynaklardan elde edilirken, non-hem demir bitkisel kaynaklardan alınır ve emilimi hem demire göre daha zordur. Fenolik bileşikler, özellikle bitkisel kaynaklardan alınan non-hem demir ile etkileşime girerek bu mineralin biyoyararlanımını engelleyebilir. Fenolik asitler ve flavonoidler, demir ile şelat yaparak çözünmeyen kompleksler oluştururlar ve bu da demirin bağırsakta emilim kapasitesini önemli ölçüde azaltabilir özellikle çay, kahve, kakao ve kırmızı şarap gibi içeceklerde bulunan polifenoller, demirin emiliminde önemli bir engel oluşturur (Çizelge 1). Bu içecekler, bağırsakta tanen ve diğer fenolik bileşiklerle reaksiyona girerek, demir iyonlarını bağlar ve bu komplekslerin çözünürlüğünü azaltır. Böylece, demirin bağırsaktan geçişi ve kan dolaşımına geçişi engellenmiş olur. Ayrıca, bazı gıdalar ve içecekler, demirin emilimini azaltırken, C vitamini gibi bileşikler bu etkileşimi tersine çevirerek emilimi artırabilir. C vitamini, demir ile reaksiyona girerek demir iyonlarının indirgenmesine ve biyoyararlanımının artmasına yardımcı olur (Eylem Atak & Mehmet Emin Uslu, 2018).

Çizelge 1. Demir biyoyararlılığında etkili başlıca ana artırıcı ve azaltıcı etki sağlayan gıda ve bileşenler (Çağındı, 2020a).

Etki	Gıda	Bileşen	Mekanizma	Açıklama
Artırıcı etki	Narenciye meyveleri, meyve suları, sebzeler	Askorbik asit	Bağırsakta çözünür kalan ve Fe^{3+}'in Fe^{2+}'ya indirgenen çözünür demir-askorbat komplekslerinin oluşumunda her ikisi de emilimi destekler	Askorbik asidin demir emiliminde güçlü bir artırıcı etkisi bulunmaktadır. Ancak ortamda ısı varlığında kolayca bozunabilmektedir.
	Et, balık, kümes hayvanları	Hayvansal bileşenler	Demirin sindirim ürünlerine bağlanması sonucu proteinlerin çözünen bileşikler oluşturması	Termal proseslerden etkilenmemektedir.
Azaltıcı etki	Tam taneli tahıl, kuruyemiş, baklagiller	Fitik asit	Bağırsakta çözünmeyen demir fitat komplekslerinin oluşumu	Yüksek diyet lifi içeren gıdalar en önemli inhibitördür.
	Çay, kahve, kakao	Polifenoller	Bağırsakta demir ile çözünmeyen komplekslerin oluşumu	Çay polifenolleri en güçlü inhibitör olarak bilinmektedir
	İnek sütü, süt ürünleri	Süt Proteini Kalsiyum	Tüm kazein ve α-kazein fosfo peptitleri, demire bağlanarak emilimini güçlü bir şekilde engellemektedir. Hem ve hem olmayan demirlerin emilimi azalır.	Peynir altı suyu proteinleri inhibitör değildir. *In vitro* testlerden ve insanlarda epidemiyolojik çalışmalardan elde edilen sonuçlar dahilinde gözlemlenmiştir.

3.2. Çinko ile Etkileşim

Çinko, hücresel işlevler, bağışıklık fonksiyonu, DNA sentezi ve protein sentezi gibi kritik biyolojik süreçlerde önemli bir mineraldir. Fenolik bileşiklerin çinko emilimi üzerinde etkisi genellikle olumsuzdur. Özellikle fitat içeren gıdalar (örneğin, tam tahıllar, baklagiller), çinko ile çözünmeyen kompleksler oluşturarak bu mineralin biyoyararlanımını sınırlayabilir. Ayrıca, flavonoidler ve bazı fenolik asitler de çinko ile bağlanarak onun emilimini

engelleyebilir. Örneğin, kuersetin ve gallik asit, çinko ile bağlanabilme kapasitesine sahip olup, bu bağlanma çinkonun emilimini azaltır. Çinko emiliminde olumsuz etkileri azaltmak için, diyetinize dikkat edilmesi gerekmektedir. Çinko emilimini artırıcı faktörler arasında, çinko içeren gıdaların daha iyi emilmesini sağlayacak stratejiler yer alır. Örneğin, çinko emilimini artıran bir diğer bileşik olan vitamin A ve D'nin de vücutta çinko metabolizmasında önemli rol oynadığı bilinmektedir. (Akdeniz V.D. 2016)

3.3. Kalsiyum ile Etkileşim

Kalsiyum, kemik sağlığı ve kas fonksiyonları açısından son derece önemli bir mineraldir. Kalsiyum emilimi, bazı fenolik bileşiklerin etkisi altında olumsuz şekilde değişebilir. Örneğin, oksalik asit içeren gıdalar, kalsiyum ile birleşerek çözünmeyen kalsiyum oksalat kompleksleri oluştururlar ve bu da kalsiyumun bağırsaktan emilimini engeller (Weaver & Plawecki, 1994). Ispanak, pazı ve diğer yeşil yapraklı sebzelerde yüksek oksalat içeriği bulunur ve bu da kalsiyumun biyoyararlanımını düşürür. Ayrıca, çay ve kahve gibi içeceklerde bulunan polifenoller, kalsiyumun bağırsaklardan emilimini engelleyebilir. Kalsiyumun emilimini artırıcı stratejiler de mevcuttur (Yılmaz, S.E. & Yılmaz, D.A 2024). Özellikle, kalsiyum içeren gıdaların C vitamini ve magnezyum gibi besin öğeleriyle birlikte tüketilmesi kalsiyumun emilimini artırabilir. Bununla birlikte, kalsiyum emilimini etkileyen faktörlerin dengeli bir şekilde yönetilmesi gerekmektedir. Örneğin, oksalat içeriği yüksek gıdaların aşırı tüketiminden kaçınılması ve kalsiyum içeren besinlerin uygun kombinasyonlarla tüketilmesi önerilmektedir (Guéguen & Pointillart, 2000).

3.4. Magnezyum ile Etkileşim

Magnezyum, hücresel enerji üretimi, sinir iletimi ve kas fonksiyonları gibi birçok biyolojik süreçte yer alır. Fenolik bileşiklerin magnezyum emilimi üzerindeki etkisi henüz tam olarak anlaşılmamış olsa da, bazı çalışmalarda fenolik bileşiklerin magnezyumun biyoyararlanımını artırabileceği belirtilmiştir. Özellikle flavonoidler ve bazı fenolik asitlerin magnezyum ile etkileşimde bulunarak bu mineralin emilimini kolaylaştırdığı gözlemlenmiştir. Ancak, bazı gıdalarda bulunan yüksek miktarda fitat ve oksalatlar, magnezyumun biyoyararlanımını sınırlayabilir (Ergün, 2019).

4. Besinsel ve Sağlık Üzerindeki Etkileri

Fenolik bileşiklerin sağlık üzerindeki etkileri oldukça çeşitlidir ve bu etkiler genellikle fenolik bileşiklerin yapısal özellikleriyle ilişkilidir. Yapıları, farklı biyolojik yolları etkileyecek şekilde tasarlanmış olan fenolik bileşikler, bağışıklık sistemi, kardiyovasküler sağlık, kanserle mücadele ve metabolik hastalıklar gibi bir dizi sağlık sorunu üzerinde doğrudan etki gösterebilir.

4.1. Antioksidan Etkiler ve Oksidatif Stres

Fenolik bileşiklerin en belirgin özelliklerinden biri, güçlü antioksidan etkinlikleridir. Antioksidanlar, serbest radikalleri ve reaktif oksijen türlerini (ROS) nötralize ederek oksidatif stresin zararlı etkilerini azaltır. Oksidatif stres, hücresel bileşenlerin (özellikle DNA, lipitler ve proteinler) oksijen radikalleriyle hasar görmesine yol açabilir ve bu da yaşlanma, kanser, kardiyovasküler hastalıklar, nörolojik hastalıklar gibi bir dizi hastalığın gelişmesine neden olabilir. Fenolik bileşikler, bu serbest radikalleri etkili bir şekilde temizleyerek hücresel düzeyde korunmayı sağlar. Örneğin, flavonoidler ve fenolik asitler, biyolojik sistemlerde güçlü antioksidan özellikler göstererek lipid peroksidasyonunu inhibe eder ve DNA hasarını azaltır. Bu bileşiklerin antioksidan etkileri, kanser hücrelerinin büyümesini engellemeye, kardiyovasküler hastalıkların riskini azaltmaya ve sinir hücrelerini oksidatif hasardan korumaya yardımcı olabilir (Yılmaz, 2010).

4.2. Anti-inflamatuvar Etkiler

Fenolik bileşiklerin anti-inflamatuvar özellikleri, inflamasyonla ilişkili hastalıkların önlenmesinde kritik bir rol oynar. Kronik inflamasyon, Alzheimer hastalığı, artrit, kalp hastalıkları ve bazı kanser türleri gibi bir dizi hastalığın gelişiminde önemli bir faktördür. (Baradaran vd., 2014). Fenolik bileşikler, inflamasyonu modüle eden biyokimyasal yolları etkileyerek bu hastalıkların riskini azaltabilir. Flavonoidler ve stilbenler gibi fenolik bileşiklerin, bazı inflamasyonla ilişkili proteinlerin aktivitesini inhibe ederek inflamasyonu azaltabildiği gösterilmiştir. Ayrıca, fenolik bileşiklerin, iltihaplanmayı kontrol eden sitokinlerin üretimini düzenleyerek bağışıklık sistemini dengeleyebileceği de araştırmalarla desteklenmektedir (Rafieian-Kopaei et al., 2014).

3. Kanserle Mücadele

Fenolik bileşiklerin kanserle mücadeledeki potansiyel etkileri, onların hücre döngüsünü düzenleyebilme, apoptoz (programlanmış hücre ölümü) indükleyebilme ve kanser hücrelerinin metastazını engelleyebilme yeteneklerinden kaynaklanmaktadır. Özellikle antosiyaninler, flavonoidler ve stilbenler, kanser hücrelerinin çoğalmasını engelleyerek tümör büyümesini yavaşlatabilir. Resveratrol gibi stilbenler, kanser hücrelerinin çoğalmasını engelleyebilen ve kanserin yayılmasını önleyebilen bileşikler arasında yer alır. Yapılan çalışmalar, resveratrolün çeşitli kanser türlerine karşı etkili olduğunu, özellikle meme, kolon ve prostat kanserinde potansiyel bir tedavi aracı olabileceğini göstermektedir (Neuhouser, 2004).

4. Kardiyovasküler Sağlık

Fenolik bileşikler, kardiyovasküler hastalıkların risk faktörlerini azaltabilir. Özellikle, flavonoidlerin, kan basıncını düşürme, damar sağlığını iyileştirme, kolesterol seviyelerini dengeleme ve kan pıhtılaşmasını engelleme gibi etkileri bulunur. Bu etkiler, kalp hastalıkları ve inme riskini önemli ölçüde azaltabilir. Örneğin, yeşil çayda

bulunan kateşinler, arter duvarlarında oksidatif stresi azaltarak damar tıkanıklığını engeller. Ayrıca, flavonoidler ve antosiyaninler, kolesterol düzeylerini düşürerek aterosklerozun önlenmesinde yardımcı olabilir. Yapılan epidemiyolojik çalışmalar, flavonoid açısından zengin gıda tüketiminin kalp hastalıkları üzerindeki etkilerini olumlu yönde göstermektedir (Muhsiroğlu, 2017).

5. Metabolik Hastalıklar ve Obezite

Fenolik bileşiklerin metabolik hastalıklar üzerindeki etkileri, şeker metabolizması, insülin duyarlılığı ve yağ depolanması gibi süreçlere müdahale edebilme yeteneklerinden kaynaklanmaktadır. Özellikle fenolik bileşikler, insülin direncini azaltabilir, kan şekeri seviyelerini düzenleyebilir ve obeziteyi önleyebilir. Örneğin, yeşil çayda bulunan kateşinler, yağ oksidasyonunu artırarak ve karaciğerdeki yağ birikimini azaltarak obeziteyi kontrol altına alabilir. Bunun yanı sıra, fenolik bileşiklerin bağırsak mikrobiyotasını olumlu yönde etkileyerek, metabolik hastalıkların gelişim riskini azaltabileceği de gösterilmiştir (Yurt, t.y.).

5. Sonuç ve Öneriler

Fenolik bileşikler ve mineraller arasındaki etkileşimler, hem beslenme bilimlerinde hem de klinik beslenme alanında önemli bir araştırma konusudur. Bu etkileşimlerin, vücudun mineral emilimi ve biyoyararlanımını etkileyebilmesi, özellikle mineral eksiklikleri veya dengesiz beslenme ile ilişkili sağlık sorunları açısından kritik sonuçlar doğurabilir. Fenolik bileşiklerin aşırı alımı, demir, çinko, kalsiyum ve diğer minerallerin biyoyararlanımını sınırlayarak, beslenme dengesizliğine yol açabilir. Bu nedenle, fenolik bileşiklerin içeriği yüksek olan gıdaların tüketimi, belirli minerallerin emiliminden olumsuz etkilenmemek için dikkatlice izlenmelidir (Yılmaz, S.E. & Yılmaz, D.A 2024). Özellikle demir eksikliği ve anemi gibi durumlar, fenolik bileşiklerin aşırı tüketimiyle ilişkili olabilir. Özellikle bitkisel kaynaklardan beslenen bireylerde, çay, kahve ve kakao gibi fenolik bileşiklerce zengin gıdaların fazla tüketimi, demir emilimini önemli ölçüde azaltabilir. Bu durum, demir eksikliği riski taşıyan bireylerde beslenme stratejilerinin gözden geçirilmesini gerektirir. Demir, kalsiyum ve çinko gibi minerallerin emilimi, C vitamini, organik asitler gibi emilimi artırıcı faktörlerle desteklenebilir. Örneğin, demir emiliminin artırılması amacıyla C vitamini içeren gıdaların, demir içeren gıdalarla birlikte tüketilmesi önerilmektedir. Ayrıca, minerallerin emilimi üzerinde olumsuz etkileri azaltmak için bazı stratejiler kullanılabilir. Fenolik bileşiklerin emilimi sınırlayan etkilerini dengelemek adına, bu bileşenlerin emilim zamanlarının ve besinlerin tüketilme sırasının optimize edilmesi önemlidir. Örneğin, demir ve çinko emilimini artırıcı C vitamini içeren gıdaların fenolik bileşiklerle zenginleşmiş gıdalarla aynı öğünde tüketilmesi önerilebilir (Çağındı, 2020b). Fenolik bileşiklerin minerallerle etkileşimleri, sadece minerallerin emilimini değil, aynı zamanda vücutta bu minerallerin biyolojik aktivitelerinin düzenlenmesini de etkileyebilir. Örneğin, fenolik bileşiklerin antioksidan özellikleri, serbest radikallerin nötralize edilmesinde önemli bir rol oynar. Bu da, özellikle oksidatif stresle ilişkili hastalıkların önlenmesinde faydalı olabilir. Ancak, fenolik bileşiklerin aşırı tüketimi ve minerallerin emilimi üzerindeki olumsuz etkiler göz önünde bulundurularak, dengeli ve çeşitli bir diyetin önemi vurgulanmalıdır. Sonuç olarak, fenolik bileşikler ve mineraller arasındaki etkileşimlerin beslenme üzerinde önemli etkileri vardır. Bu etkileşimlerin daha iyi anlaşılması, beslenme ve sağlık alanında daha etkili stratejiler geliştirilmesine yardımcı olabilir. Beslenme planlaması yapılırken, bu etkileşimlerin dikkate alınması ve dengeli bir diyetin oluşturulması, mineral eksikliklerinin önlenmesi ve optimal sağlık durumunun korunması için gereklidir. Ayrıca, bu alandaki gelecekteki araştırmalar, fenolik bileşiklerin minerallerle olan etkileşimlerini daha da netleştirerek, daha etkili beslenme rehberleri ve müdahaleleri geliştirilmesine olanak sağlayacaktır.

Öneriler:

1. **Fenolik Bileşiklerin Tüketimi ve Mineral Emilimi:** Fenolik bileşiklerin yanlış tüketimi mineral emilimini engelleyebilir. Bu nedenle, fenolik bileşiklerce zengin gıdalarla birlikte mineral emilimini artırıcı gıdaların (örneğin, C vitamini) tüketilmesi önerilir.
2. **Bilinçli Diyet Planlaması:** Minerallerin emiliminde olumsuz etkileri azaltmak için diyetlerin dengeli ve çeşitlendirilmiş olması gerekmektedir. Özellikle bitkisel kaynaklardan beslenen bireyler, demir ve çinko emilimini artırıcı gıdalara yönlendirilmelidir.
3. **Bireysel İhtiyaçlar:** Her bireyin beslenme ihtiyaçları farklıdır, bu nedenle fenolik bileşiklerin ve minerallerin etkileşimleri, kişiye özel beslenme planlamalarıyla yönetilmelidir. Özellikle demir, çinko ve kalsiyum eksikliği riski taşıyan bireyler için uygun stratejiler belirlenmelidir.

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Effects of GA_3 and PLGA-Controlled Release of GA_3 on the Germination of Caraway (*Carum carvi* L.)

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Abstract

This study was conducted to evaluate the effects of gibberellic acid (GA_3) applied at different concentrations and its combination with PLGA (poly(lactic-co-glycolic acid)) controlled-release systems on the germination of *Carum carvi* L. seeds. The experiment was designed as a factorial trial in a completely randomized plot design using five treatments: control (distilled water), GA_3 at 150 and 300 mg/L, and GA_3 + PLGA combinations at 150 and 300 mg/L concentrations. Germination percentage (%), mean germination time (days), and germination index (speed) were analyzed. The results showed that GA_3 applied alone resulted in poor or no germination. In contrast, the combination of GA_3 with PLGA significantly improved both the germination rate and speed, providing more stable germination compared to the control group ($P \leq 0.05$). Notably, the PLGA + 300 mg/L GA_3 treatment exhibited the highest performance, achieving a germination rate of 42.86% and a germination index of 5.01. No significant differences were observed between the control and PLGA + GA_3 treatments in terms of mean germination time. Moreover, while growth regression was observed in the control group after the 14th day, the PLGA + GA_3 treatments resulted in healthier and more sustained seedling development. These findings suggest that PLGA is an effective carrier for the controlled release of growth regulators such as GA_3 and can positively influence germination and early seedling development in medicinal and aromatic plants like *Carum carvi* L.

Keywords: Carum carvi *L., GA_3, PLGA, Germination*

Introduction

Carum carvi L. (commonly known as caraway) is an annual or biennial aromatic and medicinal plant belonging to the Apiaceae (Umbelliferae) family. Its natural distribution spans Western Asia, Europe, and North Africa, and it is also an integral part of the Turkish flora (Goyal et al., 2018). The seeds of *Carum carvi* L. are particularly notable for their high essential oil content, with carvone (55–60%) and limonene (30–40%) being the primary constituents (Öztürk et al., 2018). Pharmacologically, this species exhibits a wide spectrum of bioactivities, including antioxidant, antimicrobial, anticancer, hepatoprotective, anticholinergic, analgesic, and antidiabetic properties (Agnihotri et al., 2024). Consequently, *C. carvi* L. continues to be widely used in traditional medicine and has found increasing applications in modern pharmaceutical formulations.

As is common in many aromatic and medicinal plants, the germination rate of *C. carvi* L. seeds can be adversely affected by factors such as genetic variation, seed dormancy, and environmental conditions (Galambosi & Peura, 1996). In particular, low and delayed germination rates constitute major limiting factors for the commercial cultivation of this species. Seed germination represents a critical stage in the plant life cycle and directly influences agricultural productivity. Accordingly, various chemical and biological treatments have been developed to improve germination success. Among these treatments, gibberellic acid (GA_3) plays a pivotal role in breaking physiological dormancy and stimulating metabolic activation in the embryo (Miransari & Smith, 2014).

Despite the high essential oil content and medicinal value of *C. carvi* L., research focused on improving its germination through biostimulants and growth regulators remains limited. A study by Mirmazloum et al. (2020) demonstrated that osmopriming treatments using various chemical solutions (PEG, KNO_3, KCl) positively affected germination and early seedling development in *C. carvi* L. seeds. In contrast, the germination-promoting effects of GA_3 have been well-documented in numerous plant species. For example, GA_3 application significantly increased the germination rate of *Capsicum chinense* seeds (Mendoza-Gómez et al., 2021) and both improved the germination rate and reduced the germination period in *Sorghum bicolor* (Kamal et al., 2025).

Recent advancements in agricultural biotechnology have highlighted the potential use of biodegradable polymers, particularly poly(lactic-co-glycolic acid) (PLGA), in controlled-release delivery systems. PLGA is a biologically degradable polymer widely used in sustained-release nanosystems (Yang et al., 2024). Studies have shown that PLGA nanoparticles can be absorbed by plant roots and translocated within plant tissues, allowing active compounds such as GA_3 to be protected from environmental stressors and delivered to the seed surface in a more prolonged and effective manner (Vishwakarma et al., 2023). Experiments with *Arabidopsis thaliana* have demonstrated the effectiveness of PLGA in substance transport and its potential to enhance root development post-germination (De Angelis et al., 2023).

The present study aims to investigate the effects of different doses of GA_3 and GA_3 + PLGA combinations on germination rate, germination speed, and mean germination time in *C. carvi* L. seeds. Furthermore, this research will evaluate whether the controlled-release system provided by PLGA enables the physiological effects of GA_3 to be sustained in a more prolonged and balanced manner.

Materials and Methods

This study was conducted at the Plant Biotechnology Laboratory of the Department of Field Crops, Faculty of Agriculture, Selçuk University. The plant material used in this research was *Carum carvi* L. (caraway), an annual aromatic and medicinal species. The seeds were obtained from the Zeytinburnu Medicinal Plants Garden. For the experimental treatments, Resomer RG 503H-type poly(lactic-co-glycolic acid) (PLGA) (Sigma-Aldrich, 719870) and gibberellic acid (GA_3) (Sigma-Aldrich, 77065) were employed.

To evaluate seed germination performance, five different treatments were established: (1) a control treatment with distilled water, (2) GA_3 applied at two concentrations (150 mg/L and 300 mg/L), and (3) GA_3 + PLGA combinations prepared at the same two concentrations (150 mg/L and 300 mg/L). The experiment was arranged in a factorial design within a completely randomized block design (CRBD) with three replications per treatment. In each petri dish, 35 seeds were placed. Prior to germination, seeds were surface-sterilized using a 5% (v/v) sodium hypochlorite (NaClO) solution for 10 minutes, followed by three rinses with distilled water (Tanur & Yorgancılar, 2020). Subsequently, seeds were dried for 24 hours on filter paper at room temperature to restore their original moisture content. The dried seeds were uniformly arranged in sterile petri dishes lined with double layers of Whatman filter paper. Throughout the germination period, treatment solutions (GA_3 and GA_3 + PLGA) were applied at a volume of 10 mL every other day. Petri dishes were incubated under dark conditions at 25 ± 2 °C in a climate chamber for 14 days or until no further germination was observed. Daily observations were performed, and seeds were considered germinated when radicle emergence reached 5 mm (Demir & Mavi, 2008). At the end of the experiment, germination performance was assessed based on germination percentage, germination index, and mean germination time, calculated using the following formulas:

- **Germination Percentage (%)** = $(G / T) \times 100$

  G: Number of germinated seeds, T: Total number of seeds
- **Germination Index (GI)** = $N_1/T_1 + N_2/T_2 + ... + N_n/T_n$

N: Number of seeds germinated on a given day, T: Number of days (Kader & Jutzi, 2004)

- **Mean Germination Time (MGT)** = $\sum(f \times x) / \sum f$

f: Number of seeds germinated on a given day, x: Number of days (Ellis & Roberts, 1981)

The obtained data were subjected to analysis of variance (ANOVA) using the JUMP statistical software, and differences among treatment means were determined by Tukey's multiple comparison test at the $P<0.05$ significance level.

Results and Discussion

Effects of GA_3 and PLGA-Controlled Release Treatments on Germination Dynamics of *Carum carvi* L.

An evaluation of the germination dynamics of *Carum carvi* L. seeds revealed that germination commenced on the 7th day and no additional germination was observed beyond the 14th day. Notably, in the control treatment (distilled water), some seeds exhibited inhibited or regressed radicle and shoot development after the 14th day. In contrast, the PLGA + GA_3 combinations promoted post-germination development, resulting in healthier and more sustainable seedling growth. According to the findings, on the 7th day, the highest germination rate (26.67%) was recorded in the control group, while the PLGA + GA_3 treatments at 150 mg/L and 300 mg/L concentrations exhibited similar germination rates of 22.86% and 21.90%, respectively. In the groups treated solely with GA_3, germination rates remained below 1%, and in some cases, no germination was observed at all (Table 1).

Table 1. Effects of GA_3 and PLGA-Controlled Release GA_3 Treatments on Germination Percentage (%) of *Carum carvi* L. Seeds Over Time

Days	Control	150 mg/L GA_3	300 mg/L GA_3	PLGA +150 mg/L GA_3	PLGA +300 mg/L GA_3	Mean
7	26.67bd	0.95e	0.00e	22.86cd	21.90d	**14.48B**
9	34.29ac	1.90e	0.00e	37.14ab	40.95a	**22.86A**
12	38.10ab	3.81e	0.00e	40.95a	42.86a	**25.14A**
14	38.10ab	4.76e	0.00e	40.95a	42.86a	**25.33A**
Mean	**34.29A**	**2.86B**	**0.00B**	**35.48A**	**37.14A**	
Day:**, Treatment:**, Dayxtreatment:* (**$P \leq 0.01$, *$P \leq 0.05$)						

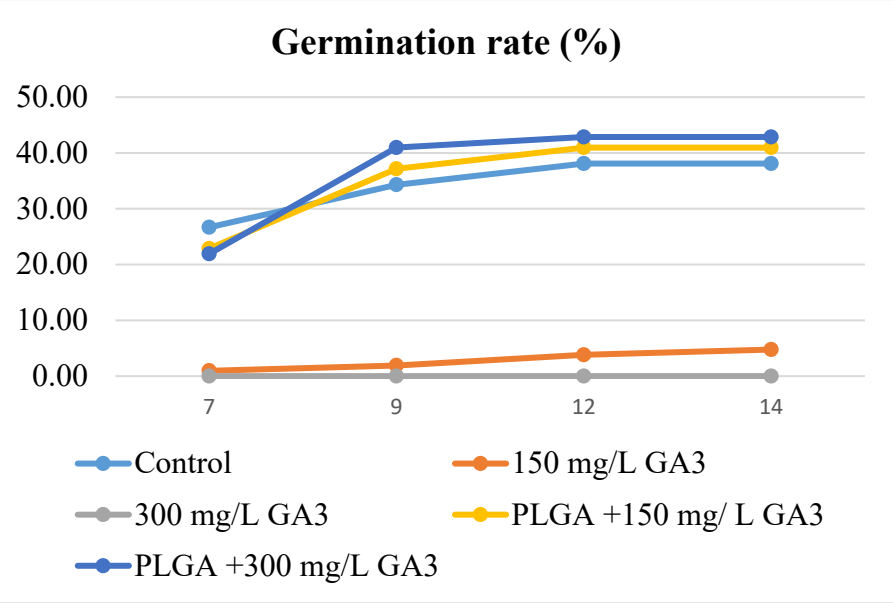


Figure 1. Time-Dependent Changes in Germination Rate (%) of *Carum carvi* L. Under GA_3 and PLGA-Controlled Release Treatments

During the subsequent days of the experiment, particularly on the 9th, 12th, and 14th days, the germination rate of the PLGA + GA_3 combinations increased sharply, exceeding 40%. On the 14th day, the highest germination rate (42.86%) was achieved with the PLGA + 300 mg/L GA_3 treatment, while the control group reached a maximum of 38.10%. In contrast, the GA_3-only treatments consistently showed germination rates below 5%, indicating the ineffectiveness of GA_3 alone in stimulating germination (Figure 1).

In general, the control and PLGA + GA_3 treatments were statistically grouped together, exhibiting similar germination rates, while the GA_3-only groups displayed significantly lower germination performance ($P \leq 0.01$). Additionally, it was observed that germinated seeds in the control group exhibited growth cessation or even regression after the 14th day. However, the PLGA + GA_3 treatments supported post-germination seedling development and ensured continued growth.

Analysis of variance (ANOVA) revealed that the main effects of day, treatment, and their interaction (day × treatment) were all statistically significant ($P \leq 0.01$, $P \leq 0.05$). These results indicate that both treatment type and temporal variation were critical determinants of the germination process.

Effects of GA_3 and PLGA-Controlled Release Treatments on Germination Index (GI) and Mean Germination Time (MGT) of *Carum carvi* L.

The effects of different treatments on the germination index (GI) and mean germination time (MGT) of *Carum carvi* L. seeds were investigated, and the results were found to be statistically significant ($P \leq 0.05$), with distinct differences detected among the treatments (Table 2).

In terms of germination speed, the highest GI value (5.01) was recorded in the PLGA + 300 mg/L GA_3 treatment, followed by the PLGA + 150 mg/L GA_3 (4.81) and the control (4.73) treatments. In contrast, the groups treated solely with GA_3 exhibited extremely low germination speeds, with a GI of 0.35 in the 150 mg/L GA_3 group and 0.00 in the 300 mg/L GA_3 group due to the absence of germination. These findings indicate that GA_3 applied alone negatively affected germination speed in *C. carvi* L., while its combination with PLGA mitigated this inhibitory effect and significantly improved germination performance.

Table 2. Effects of GA_3 and PLGA-Controlled Release GA_3 Treatments on Germination Index (GI) and Mean Germination Time (MGT) of *Carum carvi* L.

	GI	MGT (day)
Control	4.73a	10.83a
150 mg/L GA_3	0.35b	8.13ab
300 mg/L GA_3	0.00b	0.00b
PLGA +150 mg/ L GA_3	4.81a	10.99a
PLGA +300 mg/L GA_3	5.01a	11.01a
	*$P \leq 0.05$	*$P \leq 0.05$

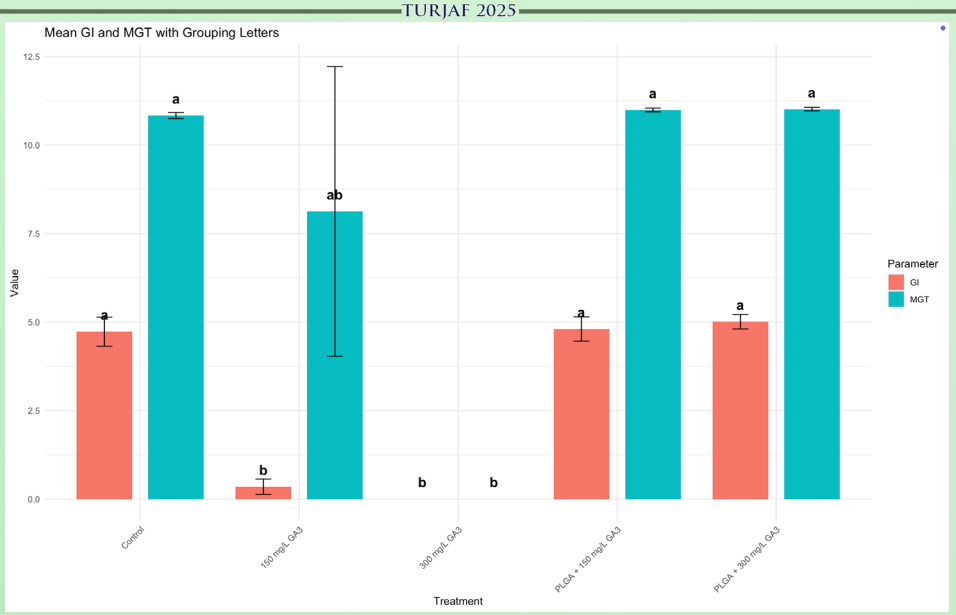


Figure 2. Comparison of GI and MGT Among Different GA_3 and PLGA-Controlled Release Treatments in *Carum carvi* L.

Regarding mean germination time (MGT), similar and statistically comparable values were observed among the control (10.83 days), PLGA + 150 mg/L GA_3 (10.99 days), and PLGA + 300 mg/L GA_3 (11.01 days) treatments. However, the 150 mg/L GA_3 treatment showed a shorter MGT of 8.13 days, although its biological relevance was limited due to the low germination speed and poor overall germination performance. In the 300 mg/L GA_3 group, no MGT value could be calculated due to the absence of germination (Figure 2).

Overall, the results revealed that GA_3, when combined with PLGA, enhanced the germination speed while maintaining a mean germination time comparable to the control group. In contrast, GA_3 applied alone resulted in reduced germination speed and poor germination performance. Statistical analysis confirmed significant differences among treatments for both germination index and mean germination time ($P \leq 0.05$).

The findings of this study clearly demonstrate that the direct application of GA_3 was insufficient to effectively promote germination and seedling development in Carum carvi L. However, when GA_3 was applied via a controlled-release system using PLGA, both germination rate and seedling development were significantly improved. This result is particularly noteworthy considering the presence of morphophysiological dormancy, which is common among species within the Apiaceae family. Similar patterns have been reported in the literature. For example, studies on *Ferula assa-foetida* (Rajabian et al., 2007), *Kelussia odoratissima* (Etemadi et al., 2010) and *Ducrosia anethifolia* (Ashtari et al., 2013) have shown that GA_3 alone had a limited effect on promoting germination, but its effectiveness improved when combined with additional environmental cues such as cold stratification.

In the present study, the combination of GA_3 with PLGA notably enhanced the germination rate (~42%) and germination speed (GI = 5.01) while supporting sustained seedling development. This improvement can be attributed to the controlled-release capabilities of PLGA. Biodegradable polymers like PLGA have gained attention in recent years for their potential use in seed coating and as carriers for plant growth regulators (Shakiba et al., 2020). PLGA adheres to the seed surface, creating a localized environment that retains the hormone near the root and shoot zones, thereby minimizing rapid degradation caused by environmental factors and enabling the gradual and balanced release of the hormone (Bonser et al., 2023).

Consistent with these findings, other studies have reported similar benefits of polymer-based delivery systems. For instance, GA_3 encapsulated within alginate/chitosan polymer matrices improved germination and yield in *Solanum lycopersicum* (Pereira et al., 2019). Likewise, the slow release of metolachlor using mPEG-PLGA nanocarriers was successfully achieved in plants (Gao et al., 2018).These findings highlight that polymer-based carriers are not only effective for pesticide delivery but also for the controlled release of plant growth regulators.

In this study, the slow-release effect provided by PLGA appears to have reduced the potential phytotoxicity of GA_3 in *C. carvi* L., a species characterized by strong seed dormancy, and allowed for the sustained delivery of physiologically tolerable doses of the hormone. This resulted in a significant improvement in both germination performance and early seedling development.

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Conclusion

Controlled release systems present an effective strategy to overcome common challenges such as low germination rates and poor seedling development, especially in species belonging to the Apiaceae family. Our findings demonstrated that the use of GA_3 through controlled release formulations, rather than direct application, significantly optimizes both germination and seedling growth. Specifically, in *Carum carvi* L. seeds, GA_3 alone had limited and low impact on germination, whereas its combination with PLGA notably enhanced both germination and seedling vigor. These results are largely consistent with previous reports on various Apiaceae species, highlighting the potential of controlled release systems to improve propagation efficiency in this important plant family.

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Evaluation of the Antifungal Effects of *Datura stramonium* Extracts on *Sclerotinia sclerotiorum* and *Rhizoctonia solani* under *In Vitro* Conditions

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Abstract

In this study, the antifungal effects of methanol and ethanol extracts obtained from the aerial green parts of *Datura stramonium* were investigated under *in vitro* conditions against the significant plant pathogens *Sclerotinia sclerotiorum* and *Rhizoctonia solani*. These pathogens cause severe losses in the production and yield of many plant species. Different concentrations (1.0%, 2.0%, and 4.0%) of *Datura stramonium* extracts were applied to both pathogens, and the obtained data were compared. The results revealed that the methanolic extract exhibited higher antifungal activity compared to the ethanolic extract. Accordingly, the methanol extract provided 12% greater inhibition against *S. sclerotiorum* and 22% greater inhibition against *R. solani* than the ethanol extract. It was observed that the antifungal effect increased in a dose-dependent manner, and at a 4.0% concentration in both solvents, mycelial growth of *S. sclerotiorum* and *R. solani* was completely inhibited. The highest inhibition effect was observed in the 2% concentration of the methanolic extract, where *R. solani* mycelial growth was suppressed by 77.77%, and *S. sclerotiorum* by 72.22%. In contrast, the antifungal activity of ethanolic extracts at the same concentration was found to be lower. In conclusion, extracts obtained from the aerial green parts of *Datura stramonium* have been shown to possess antifungal potential against plant pathogens when dissolved in different solvents. This suggests that they could be evaluated as a natural biofungicide source for controlling phytopathogenic fungi.

Key Words: *Datura stramonium, Plant pathogens, Organic solvents, Antifungal activity, Biological control.*

Datura stramonium Ekstraktlarının *In Vitro* Koşullarda *Sclerotinia sclerotiorum* ve *Rhizoctonia solani* Üzerine Antifungal Etkilerinin Değerlendirilmesi

Özet

Bu çalışmada, *Datura stramonium*'un toprak üzeri yeşil aksamından elde edilen metanol ve etanol ekstraktlarının önemli bitki patojenlerinden *Sclerotinia sclerotiorum* ve *Rhizoctonia solani*'ye karşı antifungal etkileri *in vitro* koşullarda araştırılmıştır. Bu patojenler, birçok bitki türünün üretim ve veriminde ciddi kayıplara neden olmaktadır. Çalışmada, her iki patojen üzerine farklı konsantrasyonlarda (%1,0, %2,0 ve %4,0) *Datura stramonium* ekstraktları uygulanmış ve elde edilen veriler karşılaştırılmıştır. Sonuçlar, metanolik ekstraktın antifungal etkinliğinin etanolik ekstrakta kıyasla daha yüksek olduğunu ortaya koymuştur. Buna göre metanol ekstraktının *S. sclerotiorum* üzerinde %12, *R. solani* üzerinde ise %22 oranında daha fazla inhibisyon sağladığı belirlenmiştir. Antifungal etkinin doza bağlı olarak arttığı gözlemlenmiş olup, her iki çözücüde de %4,0 konsantrasyonda *S. sclerotiorum* ve *R. solani*'nin misel gelişimi tamamen inhibe edilmiştir. En yüksek inhibisyon etkisi, metanolde çözündürülmüş %2 konsantrasyondaki ekstraktlarda tespit edilmiş olup, *R. solani*'nin misel gelişimi %77,77, *S. sclerotiorum*'un misel gelişimi ise %72,22 oranında baskılanmıştır. Aynı konsantrasyonda etanolik ekstraktların antifungal aktivitesinin daha düşük olduğu belirlenmiştir. Sonuç olarak, *Datura stramonium* toprak üzeri yeşil aksamından elde edilen ekstraktlarının farklı çözücülerde çözündürülerek bitki patojenlerine karşı antifungal potansiyele sahip olduğu ortaya konmuş ve fitopatojenik fungusların kontrolünde doğal bir biyofungisit kaynağı olarak değerlendirilebileceğini göstermektedir.

Anahtar Kelimeler: *Datura stramonium, Bitki patojenleri, Organik çözücüler, Antifungal aktivite, Biyolojik mücadele.*

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Assessment Of Food Security Among Cocoa Farming Households In Osun State, Nigeria

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Abstract

The study examines food security among Cocoa Farming Household in Osun State, Nigeria. Multistage sampling technique was used to select the 120 respondents used in this study. Analytical techniques used were the descriptive and inferential (Food security index and Logistic regression) statistics. The result revealed that 49.17% of the respondents were female, while male were 50.83%. The mean age for cocoa farming households' head was 61.1 years. Majority (83.3%) of the respondents were married. Most of the household heads in the study area had formal education. The result of the food security indices that the proportion of the food insecure households was 70% while the proportion of the food secure households was 30%. Logit result revealed that age ($p< 0.1$), sex ($p< 0.05$), household size ($p< 0.01$) and number of meal per day ($p< 0.01$) were variables significantly responsible for food security of cocoa farming households in the study area. The study therefore recommends that reduction in food insecurity should involve collaborated efforts by both the government and private sectors through regular orientation that encourages education among farm households on the need to expand their sources of income from agriculture to off-farm income generating business. In addition, farmers groups and government should provide agricultural inputs to farming households during farming seasons at affordable prices.

Keywords: *Cocoa, Food Security, Logit Regression*

Introduction

The 2023 removal of the fuel subsidy in Nigeria marks a pivotal moment in the nation's economic, social, and environmental trajectory. This decisive policy shift carries with it a multitude of implications that warrant rigorous investigation to comprehend its far-reaching consequences. The core problem at the heart of this study lies in uncovering the intricate web of impacts – positive, negative, direct, and indirect – that arise from the subsidy removal and examining their ramifications for both the Nigerian economy and society. The subsidy removal, while driven by the intent to align with global trends of fossil fuel subsidy reduction and enhance fiscal sustainability (Al Jazeera, 2023), presents a host of challenges. Foremost among these challenges is the potential exacerbation of socio-economic inequality, given that subsidy removal can lead to increased fuel prices and a subsequent rise in the cost of living, thereby leading to food insecurity. This predicament echoes the concern raised by Ude (2023), emphasizing that while subsidy elimination might hold long-term benefits, it can strain the financial resources of households, particularly those already marginalized.

Food is a vital need for all humans which must be satisfied for a healthy and productive living. Issues related to food security vis-à-vis availability, accessibility/affordability, and sustainable utilization remain pertinent for policymakers and academics. This may have stemmed from the fact that malnutrition may result in dire health and physical consequences. Arising from the 1996 World Food Summit was a holistic definition of food security which incorporates the four domains of food security namely; availability, access, utilization and stability. Food security was defined as ability of all people to have physical and economic access, at all times, to safe nutritious food to maintain a healthy and active life (Ogunniyi *et al.* 2020; Omotayo 2020). Conversely, a household becomes food insecure when such a household is unable to afford, or have access at all times to such quantity and quality of food that makes for healthy living (Obayelu and Orosile 2015). Food insecurity can be viewed as an extreme form of poverty, a state of deprivation of basic human needs to which a person, household, community, or nation can be subjected (Brimah *et al.,* 2015). Lack of resources to acquire enough food for individual or household results in insufficient nutrition, poor calorie intake and poor nutrition; a low income household may not be immune to hunger and the concomitant health challenges since constrained economic access to food would result in poor nutrition (malnutrition) which may either be chronic or transitory in natural (Mutisya *et al.,* 2015). In Nigeria, per capita calorie intake over the past two decades has fallen below the

recommended level. Evidence from the Global Food Security Index (GFSI), Nigeria ranked 91 in 109 countries and had a 37.1 weighted score out of 100 (GFSI, 2015).

Recently, in Nigeria as a whole there is a high rate of inflation which directly affects food security on the Country, (World Bank, 2018). Additionally, Nigeria is among the large exporters of agricultural products. Tree crops such as cocoa, oil palm, rubber among others has largely led agricultural exports in Nigeria. The production and export of cocoa (*Theobroma cacao*) has served as a major source of foreign exchange for many developing countries particularly in Sub-Saharan Africa (SSA). Since its discovery in the 18th century at the Amazon basin, cocoa cultivation has spread to other tropical areas of south and central, and indeed West Africa, which became the major producer from the mid-1960s. The dominance in world cocoa production shifted from America to Africa in the second half of the nineteenth century and remains so to date. Cocoa was introduced to West Africa from Brazil (South America) precisely from Fernando Po into Nigeria in 1874 and Ghana in 1879 by one Squiss Bamengo, a chief of the Niger Delta, (Eduardo and Philippe 2013). West Africa has been the centre of cocoa cultivation for many decades, as two-thirds of the world's cocoa is produced in West Africa. Currently, the main producers of cocoa are Cote D'Ivoire, Ghana, Indonesia and Nigeria. Nigeria remains the third largest producer of cocoa and sixth globally, (International Cocoa Organization, ICO, 2012). Before the emergence of black gold (crude oil) in Nigeria, cocoa was the major leading cash and export crop in Nigeria especially in southern part of Nigeria. The top growing States Ondo, Ogun, Osun Oyo and Ekiti account for about 60% of the cocoa production and make up at least 30% of the total cocoa export in Nigeria. Others are Cross River, Edo, Abia, Kwara, Kogi, Adamawa, and Akwa Ibom. But Nigerian Bureau of Statistic (2013) identified eighteen cocoa producing States in Nigeria. Therefore in addition to the aforementioned State, others are Taraba, Delta, Lagos, Bayelsa, River and Imo States. Although there have been several studies on food insecurity, some of which were Antwi and Lyford (2018), Fawole, Ozkan and Ayanrinde (2016), Awoyemi, *et al.,* (2022) but research on food insecurity among cocoa farming households most especially in Osun State, Nigeria is very terse in literature. This study therefore assesses the food insecurity among Cocoa Farming Household in Osun State Nigeria. Specifically, the study described the Socio-economic characteristic of cocoa famer in the study area, estimate the food security status of cocoa faming household in the study area, determined the factor that influencing the food security among cocoa faming household in the study area and describe the constraint associated with cocoa faming in the study area.

Methodology

This study was conducted in Osun State Nigeria. Osun State (Ìpínlẹ̀ Ọ̀ṣun), occasionally known as the State of Osun by the state government, is a State in Southwestern Nigeria; bounded to the east by Ekiti and Ondo states, to the north by Kwara State, to the south by Ogun State and the west by Oyo State. The State is known for its rich cultural heritage, historical sites, and diverse economic activities. Multistage sampling technique was used to select respondents for the study. The first stage involves population selection of Ife-east Local Government Area (LGA) because of high population of cocoa farmer compared to other LGA in the State. At the second stage, five [5] villages were randomly selected based on their involving in cocoa production. Finally, twenty five [25] cocoa farmers were randomly selected in the villages/communities earlier chosen. Making a total of 125 respondents [cocoa farmer], meanwhile, five responses were discarded due to incomplete information. The research used descriptive statistics such as the mean, frequency, percentage variance to describe the socio-economic characteristic of the respondents in the study area and Logit regression to estimate the factors responsible for food insecurity among cocoa farmers in the study area, Awoyemi, *et al.,* (2022).

Food Security Index (FSI) was adopted for this Study

Method 1

In food security index, food security line was estimated from household monthly expenditure on food items. Any households spending above 2/3 of this line are classified as food insecure while those below it are considered food secure. The food security is calculated based on the total expenditure of food items consumed by a household over the past seven days. The food security index is given as:

$$F_i = \frac{percapitafoodexpenditureforthehouseholds}{{}^{2}/_{3}\, meanpercapitafoodexpenditureinallhouseholds}$$

Where

$$per\ capita\ food\ expenditure\ (PCE) = \frac{Total\ food\ Expenditure}{Household\ Size}$$

$$mean\ per\ capita\ household\ food\ expenditure\ (MPCFHE) = \frac{Total\ household\ PCE}{Total\ number\ of\ Households}$$

$$F_i = Foodsecurityindex$$

When$F_i \geq 1 \ = foodsecureithhousehold$

$$F_i \leq 1 = foodinsecureithhousehold.$$

Method 2

In order to compute the mean per capita household expenditure index, the following equations were adopted:

$$meanpercapitahouseholdexpenditure(MPHE) = \frac{\sum_i^n K_i}{\sum_i^n H_i}$$

Where: $K_i$is the monetary value of all food items that were consumed per day by the household, $H_i$is sum of members in the household. Therefore, the proportion of households that were food secured index (FSI) was computed as:

$$FSI = \frac{m}{N}, m$$

m is the number of food secured households, N is sample population. When this is multiplied by 100, it gives the percentage of households that were food secured.

The Logit Regression (LR) Model

The LR gives each predictor a coefficient which measures its independent contribution to variation in the dependent variable. The dependent variable Y takes the value 1 if the response is "food secure" and takes a value 0 if the response is "food insecure".

The Logit equation is written as (Green, 1993).

$$P_i = \frac{e^{\beta x}}{1 + e^{\beta x}}$$

Where P_i = 1(For food secure) and 0 for food insecure. Since Logistic regression calculates the probability of success (p) over the probability of failure (q), the results of the analysis are in the form of an odds ratio (p/q).

Y = (1 if food secured and 0 otherwise)

X_1= Sex, X_2= Age, X_3= Marital Status, X_4=Schooling, X_5= Household Size, X_6= Experience, X_7= Member of Association, X_8= Extension Agent, X_9= Number of Meal per day, X_{10}= Enough Food, X_{11}= Protein Rich, X_{12}= Meal Skip, ε = error term

Results and Discussion

Socioeconomic variables of the respondents are presented in Table 1. According to the Table, 50.83% of the respondents were male, while female were 49.17%. The result shows that both male and female constituted the rural households in the study area and male forms the majority probably because many of the nature of cocoa farming activities, thus agreeing with the finding of Ndaghu et. al., (2009) and Robert *et al.,* (2013) who reported that males are the most household heads who are responsible for major production decision. This finding however disagrees with Zubairu and Maurice (2014) and Hadebe and Mpofu (2013) who found that women are mostly involved in food crop production which ensures food security. The result further shows that the mean age for cocoa farming households' head was 61 years. About 38.33% of the total respondent households' head had their age below the mean age, while about 61.67% of the respondents had their age above it. Hence, there were older households' head than their younger counterparts in the study area. However this result is similar to the result obtained by Oluyole *et al.,* (2015) who found out that the older the household head, the lower the probability that the household would be food secure. Majority (83.3%) of the respondents were married. Given the very low rate of single (25.00%), widowed (10.0%) and divorced (2.5%). This implies that majority of the respondents will have additional responsibilities to their spouses and children. This implies that there is the likelihood that there could be more family labor available to farming households (Oluyole *et al.,* 2015). Gotten from the Table, majority (85.3%) of the respondents had between 3 and 16 children with mean size of 7. This could be regarded as large family size. However it is likely that these children will be used as source of manual labor in the household, also the age at marriage will have an impact on family size. The implication of this finding is that the quantity of food intake will be affected and dependency ratio will be affected. The larger the family size the lesser food availability to each person within the household and also nutritional status is affected. The result is in agreement with Babatunde *et al.,* (2007), which depicted that as the household size increases, the probability of food security decreases. This could mean that as the household size increases, there is larger number of people to be taken care of by the same source of income. Table 1 also shows that 35.83% of the respondent spent up to 7-12 years in school. This shows that the respondent with the more years of education will find it easy to assimilate new innovation that will aid their farming activities at a faster rate, which will lead them to be more food secured. While 28.33% of the responded spend up to 6 years in school will also understand the new innovation but at a slower rate. Result from Table one shows that 46.67% of the respondent are into farming activities as their major

occupation,11.67% are into Trading, 17.50% are Civil servant ,20% are artisan, 1.67% are Medical practitioner and 1.67% are also Driver and 0.83% are retired civil servant. The results in the Table also revealed that 69.11% of the respondents belonged to associations, while 30.83% did not belong to any associations. The implication of this result is that most of the farmers in the study area will likely enjoy the benefits accruable to the farming association society's membership through pooling of resources together for a better expansion and effective management of resources.

Table 1: Socioeconomic Characteristic of the Respondents

	Frequency	Percent
Sex		
Male	61	50.83
Female	59	49.17
Age group		
21-40	15	12.50
41-60	43	25.83
61-80	54	45.0
80	8	6.67
Mean	61.1	
Marital Status		
Single	5	51.67
Married	100	83.33
Divorced	3	2.50
Widow/widower	12	10.00
Household size		
<=10	103	85.83
11-20	17	14.17
Mean	7	
Education		
<=6	34	28.33
7-12	43	35.83
>12	43	35.83
Mean	6	
Major Occupation		
Farming	56	46.67
Trading	14	11.67
Civil-servant	21	17.50
Artisan	24	20.00
Driver	2	1.67
Medical practitioner	2	1.67
Retired	1	0.83

Source: Field Survey, 2024

Food Security Status of Cocoa Faming Household

The result in Table 2 shows the food security indices for the study. The Table shows that the proportion of the food insecure households was 70% while the proportion of the food secure households was 30%

Table 2: Food Security Index

	Frequency	Percentage
Food secure	34	30.00
Food insecure	841	70.00
Total	120	100.00

Source: Field Survey, 2024

Estimate the Factor that is Influencing the Food Security among Cocoa Farming Household

A binary logistic regression analysis was conducted to estimate the factor that influencing the food security among cocoa farming household in the study area (Table 3). The dependent variable (Food Security) was captured as food insecure = 0 and food secured = 1 based on the food security line. The model is statistically significant, indicating that the explanatory variables estimated reliably distinguished between the food insecure and food secure (Chi-

square (χ^2) = 56.33, p = 0.000). Pseudo R-square value is 0.3842 indicating that 38.42% of the variation to be observed in the food insecurity situations of the cocoa farmers were explained by the combined effects of all the independent variables in the model specified. Binary logistic regression is based on four crucial assumptions that need to be addressed. First, the dependent variable should be ordinal. In this study, the dependent variable was captured as a binary variable. Secondly is the linearity assumption. Linearity in the binary logistic model assumes that independent variables have a linear relationship with the dependent variable. This assumption can be verified by checking the model fit statistics and pseudo-R-Squared (R^2). In this study, the model fit statistics and pseudo R^2 in Table 3 indicate that the model well fits data. Also, binary logistic regression does not need a linear relationship between the dependent and independent variables because it applies a non-linear log transformation to the predicted odds ratio. Thirdly is the assumption of independent errors. The assumption of independent errors states that errors should not be correlated for two observations. That is, data should be drawn from independent samples and not dependent samples such as before and after or matched pairings.

Household size variable is highly significant (p = 0.000) with a positive coefficient (β = 0.268). The results revealed that an increase in household size increases farmer's chances of becoming food insecure. The odds ratio value of 0.268 indicates that ceteris paribus, an increase in household size by one adult equivalent increases household log odds of becoming food insecure by 0.268 times. An increase in household size constraints existing income. Reduction in income reduces household consumption expenditure and hence an increase in household food insecurity. Previous studies such as Achieng (2014) and Macho (2015) found that an increase in household size, directly and indirectly, increases household poverty through reduction in income per adult equivalent which eventually impairs standard of living. Variable indicating number of meal per day is statistically significant (p = 0.003) with a positive coefficient (β = 6.198). The results revealed that number of meal per day reduces household food insecurity of cocoa farmers. The odds ratio = 6.198 means that ceteris paribus, access to number of meal per day reduces household log odds of becoming food insecure by 6.198 times and vice versa (Igbalajobi *et al.,* 2013). Variable indicating the age of household head is statistically significant (p = 0.084) with a coefficient (β = -2.009). The results means that an increase in the age of household head increases his/her chance of becoming food insecure and vice versa. The odds ratio = 1.078 shows that ceteris paribus, an increase in the age of household head one year, increases log odds of a household becoming food insecure by 1.078 times and vice versa. As the age increases, the productivity of household head decreases due to poor health associated with old age. The findings agrees with Khamaldin *et al.,* (2015). The studies revealed that the aging of the household head tends to increase the household probability of falling into food insecurity. Contrary results are reported in Akona (2014), who found that an increase in the age of household head significantly reduces household observed poverty. The study argued that as the household head grows older, he/she should accumulate more income that is sufficient to move their households out of poverty.

Table 3: Factor that is Influencing the Food Security among Cocoa Farming Household

Food Security Index	Odds Ratio	Standard Error	P>|z|	Mfx
Sex	3.050717	1.757305	0.053**	0.054
Age	1.078357	0.0470039	0.084 *	0.085
Marital Status	0.732816	0.4876246	0.640	0.642
Schooling	0.9591507	0.0909359	0.660	0.654
Household Size	0.2675977	0.0793044	0.000***	0.000
Experience	0.9193548	0.0606319	0.202	0.193
Member of Association	5.949093	7.635012	0.165	0.055
Extension agent	0.1948771	0.2248217	0.156	0.189
Number of meal per day	6.197564	3.858865	0.003***	0.002
Enough food	1.980593	1.46113	0.356	0.397
Protein rich	0.7113794	0.2342477	0.301	0.306
Meal skip	1.491939	0.9418342	0.526	0.509
Constant	0.9860974	2.107555	0.995	
Number of observations	120			
LR chi^2 (12)	56.33			
Prob > chi^2	0.0000			
Pseudo R^2	0.3842			

Source: Author's Compilation

*; ***; and *** Represents 10%; 5% and 1% significant levels respectively

Constraint to Cocoa Production

The constraints encountered by the respondents as revealed in the study indicated that higher percentage of the respondents which is 99.17% has access to land for Cocoa production. While 0.83% claimed to have no access to land for the production of cocoa as shown in Table 5. About 71.67% do not have access to good farm road and only the few 28.33% have access to good road. In Table the results also shows that 57.50% of the respondents are very much affected by pest and disease, while 40.50% are not that affected. Pest and disease of cocoa are the major challenges faced by cocoa farmer and it reduces their level of production. This shares a relationship with the research carried out by Andrew *et al.,* (2022).Which revealed that Pest and diseases represent a challenge to production to a greater or lesser extent in most Cocoa-growing regions. From the Table, 100% indicated that they are sure that there is no rituals associated with cocoa farming in the study area. The study revealed that 36.67% of the respondents had no access to credit while 63.33% have access to production credit from both formal and informal sources in terms of acquired for farm. This access to production credit by some of the respondents may not be unconnected with the fact that many of the respondents belonged to a cooperative society which is the major means of obtaining assistance either from Government or Non-Governmental Organizations (NGO). From the Table, the result of the respondent show that 36.67% faced pest and disease challenges, 25.00% faces too much rainfall, 20.83% faces monkeys infestation, 5.00% faces high prices of Agrochemicals, 4.17% faces mistletoe infestation, 5.00% faces financial problems, 1.67% faces pest and diseases and too much of rainfall and also 1.67% faces weather as major challenges.

Table 4: Constraints to cocoa production

	Frequency	Percentage
Do you have access to farm land for cocoa farming?		
No	1	0.83
Yes	119	99.17
Do you have access to good road for transportation to bring cocoa input into your farm?	Frequency	Percentage
No	86	71.67
Yes	34	28.33
How do pest and disease affect cocoa production on your farm	Frequency	Percentage
Very much	69	57.50
Not much	51	42.50
Are there cultural or rituals associated with cocoa production		
No	120	100.00
Have you had to finance cocoa farming activities		
No	44	36..67
Yes	76	63.33
What are the major challenges faced in cocoa farming		
Pest and disease	44	36.67
Too much rainfall	30	25.00
Monkey infestation	25	20.83
High price of agrochemicals	6	5.00
Mistle-toe infestation	5	4.17
Financial problem	6	5.00
Pest and disease and too much rainfall	2	1.67
Weather	2	1.67

Source: Field Survey, 2024

Conclusion

The study was necessitated due to the significance role cocoa exports play in the development of the Nigeria economy. Results from the study showed high level of food insecurity among cocoa producing households in the study area. The study therefore recommends that reduction in food insecurity should involve an integrated approach by both the government and private sectors through regular orientation that promotes education among farm households on the need to diversify their sources of income from agriculture to off-farm income generating business. In addition, Government and farmers groups should provide agricultural inputs to farming households during farming seasons at affordable prices in order to increase their farms size and food production capacity since

farm size was one of the factors that influenced farm household food security.

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Assessing Contamination Risks in Sultanköy and Altınyazı Reservoirs (Türkiye) Using Modified Organic Pollution Indices

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Abstract

Due to their lentic and enclosed nature, lakes are more susceptible to organic pollution and eutrophication. Sultanköy and Altınyazı reservoirs are located in the Edirne Province of Türkiye, where is classified as "Agricultural Land" because of its abundant freshwater resources and fertile soils. The reservoirs are exposed to organic pollution from surrounding agricultural activities and domestic wastewater. This study evaluated and compared the contamination threats for the Sultanköy and Altınyazı dam lakes by means of some modified organic contamination indices using Turkish Standards. For this purpose, nutrient pollution index (NPI) and water quality index (WQI) were selected as the organic pollution risk assessment indicators. Water samples were collected in the autumn season of 2024 and measured for 5 limnological parameters (SO_4, NO_3-N, NO_2-N, NH_4-N and PO_4-P) that are used to calculate the indices. The results revealed that although the Altınyazı Reservoir exhibits a lower potential eutrophication risk compared to Sultanköy Reservoir, the waters of both dam lakes were highly polluted.

Keywords: *Sultanköy Reservoir, Altınyazı Reservoir, Organic pollution indicators*

Introduction

Organic contaminants, particularly nutrients derived from agricultural runoff and wastewater, are critical drivers of algal bloom formation in lacustrine ecosystems (Atıcı et al., 2018; Haq et al., 2023; Din et al., 2023; Muhammad et al., 2025). These blooms, characterized by excessive algal proliferation, disrupt aquatic ecosystems by depleting dissolved oxygen, obstructing light penetration, and altering trophic dynamics. Furthermore, organic contamination contributes to the development of hypoxic zones, where oxygen concentrations decline to critically low levels (Howarth et al., 2011; Borrell et al., 2019; Mia et al., 2023). The assessment of organic contaminants is crucial for understanding their cumulative effects on aquatic biodiversity, water quality, and overall ecosystem integrity (Çiçek et al., 2014; Köse et al., 2020; Varol et al., 2022; Ustaoğlu et al., 2022; Yüksel et al., 2024). A comprehensive approach is required to effectively evaluate aquatic ecosystem health and formulate sustainable management strategies. Notably, key indicators such as the Nutrient Pollution Index (NPI) and the Water Quality Index (WQI) are widely utilized to assess the synergistic impacts of organic contamination (Tokatlı and Varol, 2021; Varol et al., 2022; Muhammad et al., 2024; Tokatlı et al., 2025).

Sultanköy and Altınyazı Dam Lakes are among the most significant reservoirs in Edirne Province, Türkiye, serving as essential water sources for both irrigation and drinking water supply. Constructed by the General Directorate of State Hydraulic Works (DSİ) to enhance agricultural productivity and fulfil the water demands of local communities, these reservoirs play a crucial role in maintaining both economic stability and ecological balance (http://www2.dsi.gov.tr/). However, similar to many freshwater ecosystems, they are increasingly subjected to anthropogenic pressures, particularly from agricultural runoff and domestic wastewater discharge. These activities introduce excessive nutrients, pesticides, suspended solids, and organic pollutants into the water bodies, posing significant risks to water quality and aquatic ecosystem health (Tokatlı et al., 2017; Tokatlı, 2019; 2020a; 2020b). This study aims to assess and compare the contamination threats affecting Sultanköy and Altınyazı Dam Lakes by employing a set of modified organic contamination indices. The evaluation is conducted in accordance with Turkish Standards, providing a comprehensive framework for analysing the extent and impact of organic pollution in these freshwater ecosystems. By utilizing standardized assessment methods, the study seeks to offer valuable insights into water quality dynamics and potential environmental risks, thereby contributing to the development of effective management and conservation strategies.

Materials and Methods

Research area and sample collection

Sultanköy and Altınyazı Dam Lakes, along with the selected sampling stations on these reservoirs, are presented in Figure 1, providing a visual representation of the study area. To evaluate the current water quality status, water

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samples were systematically collected from the designated stations during the autumn season of 2024, ensuring that potential pollutant influxes were accurately represented in the analysis.

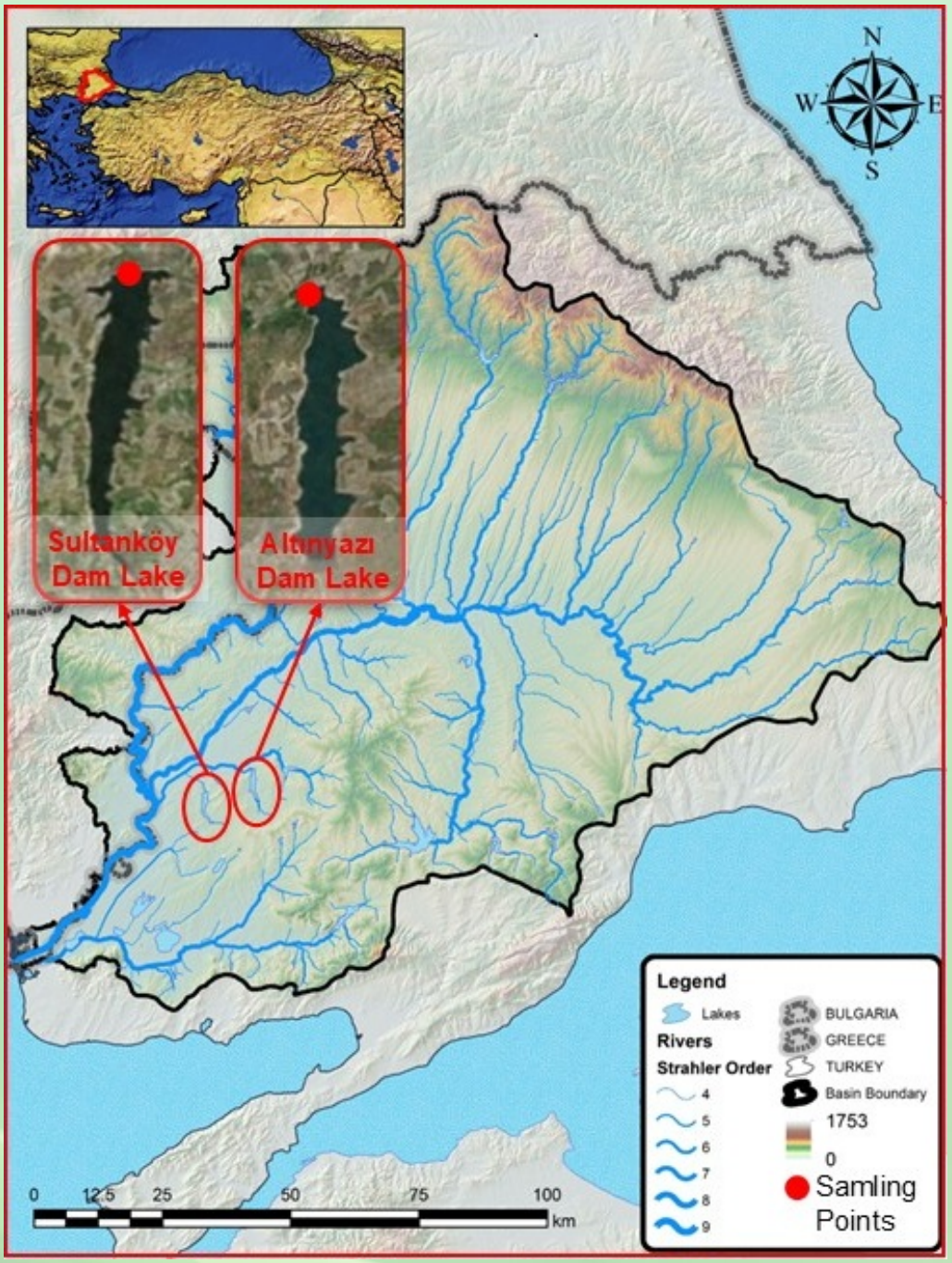


Figure 1. Meriç – Ergene Basin, investigated reservoirs and selected sampling stations

Physicochemical analysis and ecological indices

The concentrations of phosphate-phosphorus, nitrite-nitrogen, nitrate-nitrogen, ammonium-nitrogen and sulphate were analysed in the laboratory following APHA protocols (1998, 2017) using a Hach spectrophotometer and a Hach colorimeter.

The details of the formulas and computation techniques for the modified organic contamination indices applied in this study, based on the Turkish Standards (TSWQR, 2021), are provided in Table 1 (Tokatlı et al., 2025). These indices were carefully selected to assess the level of contamination and biodegradability in the water samples, ensuring an accurate representation of the environmental conditions.

Table 1. Methods of applied modified organic pollution risk assessment indices

Index	Calculation	Formula Explanations	Rating of Water Quality
NPI	$NPI = (C_N/MAC_N) + (C_P/MAC_P)$	C_N: The levels of NO_2-N in water sample C_P: The levels of PO_4-P in water sample MAC_N: The maximum limit of NO_2-N MAC_P: The maximum limit of PO_4-P	<1: No polluted 1-3: Moderate polluted 3-6: Considerable polluted >6: Very high polluted
WQI	$WQI = \sum_{i=1}^{n} Wi\ x\ (\frac{Ci}{Si})\ x\ 100$ $Wi = \frac{W_i}{\sum_{i=1}^{n} W_i}$	WI: The relative weight Wi: The values assigned to i (1-5) Ci: The values of measured parameters Si: The standard values	<50: Excellent water quality 50–100: Good water quality 100–200: Poor water quality 200–300: Very poor water quality >300: Unsuitable

Results and Discussion

The data for the calculated modified organic contamination indices for the waters of the Sultanköy and Altınyazı reservoirs are presented in Figure 2. The results indicate that although the Altınyazı Reservoir exhibits a lower potential eutrophication risk compared to Sultanköy Reservoir, the waters of both dam lakes were highly polluted. According to the applied ecological indices, it was determined that the water qualities of both reservoirs are considerably degraded, exhibiting high levels of pollution. Specifically, the Nutrient Pollution Index (NPI) were recorded as 8.10 for Sultanköy Reservoir and 6.50 for Altnyazı Reservoir, both falling into the "very high pollution" category. Similarly, the Water Quality Index (WQI) values were recorded as 284 for for Sultanköy Reservoir and 198 for Altnyazı Reservoir, classifying as "very poor water quality" and " poor water quality", respectively.

The application of chemical fertilizers, which contain considerable amounts of nitrogenous and phosphorus compounds, is a prevalent agricultural practice in the areas surrounding the reservoirs. These fertilizers, along with organic pollutants from agricultural runoff, can be transported into adjacent water bodies through multiple pathways, including irrigation, precipitation, and soil erosion (Mutlu et al., 2021a; 2021b; Jannat et al., 2022; Tokatlı et al., 2023; 2024). The accumulation of these pollutants within the reservoirs leads to excessive nutrient enrichment, thereby exacerbating the risk of eutrophication. Furthermore, domestic wastewater discharges from nearby settlements are considered a major contributing factor to the elevated ecological risk index values identified in this study, highlighting the significant anthropogenic pressures impacting these freshwater ecosystems.

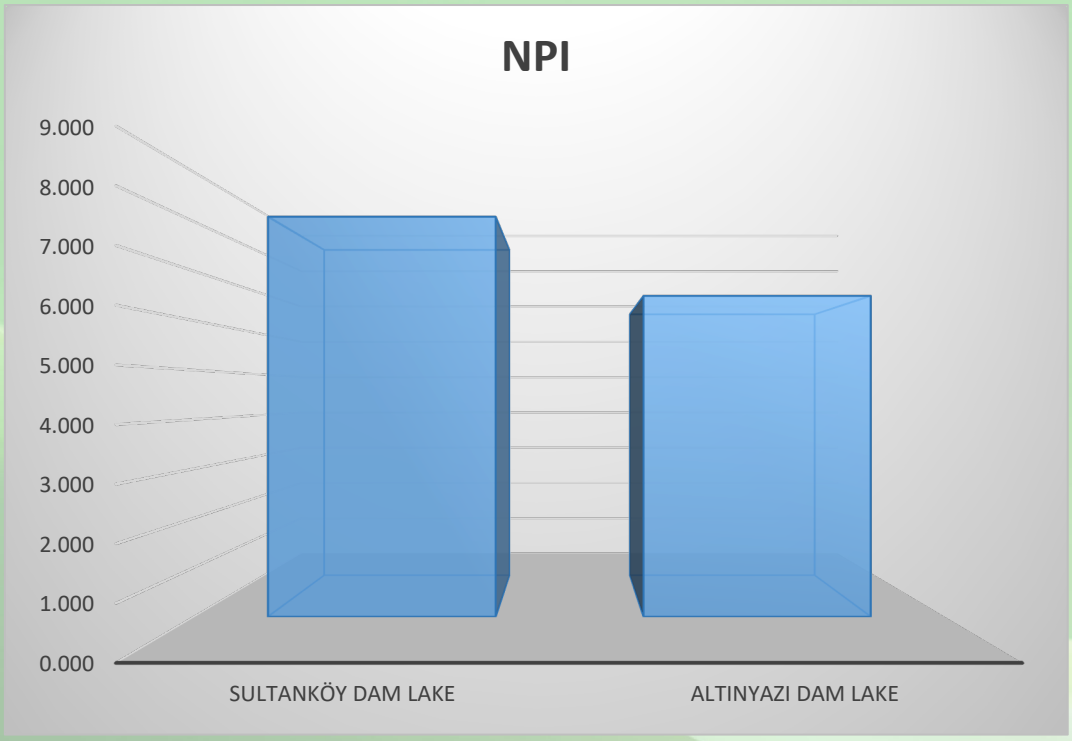


Figure 2. Results of applied NPI (up) and WQI (down) in waters of investigated dam lakes

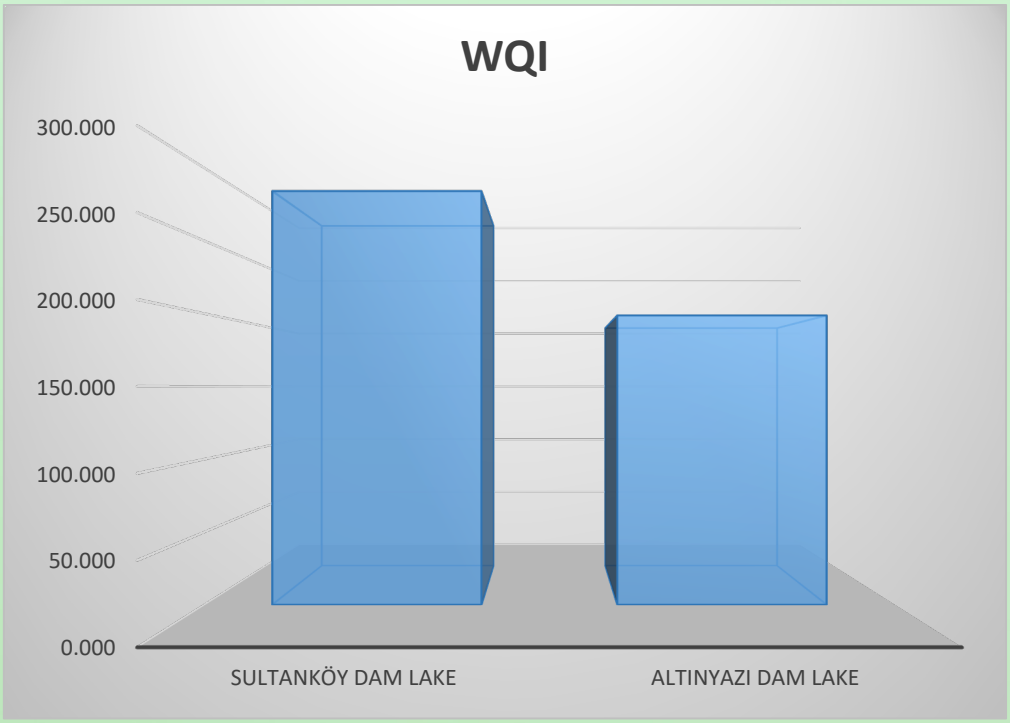


Figure 2. Results of applied NPI (up) and WQI (down) in waters of investigated dam lakes (continued)

Conclusions

The findings of this study reveal significant organic contamination in both Sultanköy and Altınyazı Reservoirs, highlighting severe water quality degradation. Although Altınyazı Reservoir exhibited a relatively lower risk of eutrophication compared to Sultanköy Reservoir, the overall pollution levels in both water bodies were alarmingly high. The calculated Nutrient Pollution Index (NPI) values of 8.10 for Sultanköy Reservoir and 6.50 for Altınyazı Reservoir indicate that both reservoirs fall within the "very high pollution" category. Similarly, the Water Quality Index (WQI) values of 284 for Sultanköy Reservoir and 198 for Altınyazı Reservoir classify the water quality as "very poor" and "poor," respectively. These results underscore the urgent need for comprehensive water management strategies to mitigate further degradation and restore ecological balance in these critical freshwater ecosystems.

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ID: 564

Comparative Aluminum Stress Tolerance in Red (Fırat-87) and Black-Seeded (Beluga) Lentils

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Abstract

Aluminum (Al) is a significant toxicant that restricts root growth in plants, even at low concentrations found in acidic soils. This study aimed to investigate the comparative Al stress tolerance of a red lentil cultivar (Fırat-87) and a black-seeded lentil cultivar (Black Beluga). Five-day-old seedlings of both cultivars were exposed to 100 µM $CaCl_2$ (control) or 100 µM $CaCl_2$ supplemented with 50 µM Al (Al treatment) under hydroponic conditions at pH 4.5 for 24 hours. Histochemical staining of Fırat-87 roots with hematoxylin demonstrated clear cracks and intense dark staining in the root apex and elongation zone, indicating a greater accumulation of Al compared to Black Beluga. Similarly, Evan's blue staining revealed cracks and dark blue staining in the root elongation zone of Fırat-87, whereas Black Beluga showed no visible cracks or dark staining. Lipid peroxidation, assessed using Schiff's reagent, exhibited pronounced dark pink staining in the root apex of Fırat-87, but only minimal staining in Black Beluga. These histochemical analyses suggest that Fırat-87 is more susceptible to Al toxicity than Black Beluga. Consistent with these findings, Black Beluga exhibited significantly higher relative root elongation (77.27%) compared to Fırat-87 (55.32%), reinforcing its Al tolerance. Quantitative real-time PCR analysis of the *LcALMT1* gene revealed significantly higher expression levels in Al-treated roots of Black Beluga compared to Fırat-87, implying that *LcALMT1* may play a crucial role in the enhanced Al tolerance observed in Black Beluga. In conclusion, these results demonstrate that Black Beluga is an Al-tolerant lentil cultivar, making it a promising candidate for cultivation in acidic soils without compromising seedling establishment and subsequent growth.

Key Words: *Aluminum toxicity, Lentil tolerance, Histochemical staining, Root elongation, LcALMT1 gene expression*

ID: 565

Preference and Purchasıng Behavıour of Selected Functıonal Foods Among Households in Ifo Local Government Area, Ogun State, Nıgerıa

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Abstract

The rising awareness of functional foods and their health benefits has influenced consumer preferences and purchasing behavior globally. However, limited research exists on the consumption patterns of functional foods in Nigeria. This study examines the determinants of functional food consumption in Ifo Local Government Area, Ogun State, using primary data collected through structured questionnaires administered physically and virtually via the KoboToolbox platform. A multistage sampling technique was employed, selecting 10 Community Development Committees (CDCs), 30 Community Development Associations (CDAs), and 300 households, with 240 valid responses for analysis. Descriptive statistics were used to assess the socio-economic characteristics, awareness levels, and purchasing behavior of respondents. A Poisson regression model was applied to identify key factors influencing functional food consumption. Findings indicate that age, marital status, and income significantly determine purchasing behavior. Family, friends, and health professionals were the primary sources of nutrition information, while local markets and roadside vendors served as major suppliers. Price and availability emerged as the most crucial factors affecting consumer choices. To enhance functional food consumption, policies should focus on improving accessibility, regulating prices, and increasing consumer awareness. Additionally, future research should expand to larger and more diverse populations to strengthen the generalizability of findings. Insights from this study provide valuable information for policymakers, food producers, and marketers to promote functional foods and support sustainable nutrition practices in Nigeria.

Key Words: *Preference, Purchasing behaviour, Functional Foods, Households, Nigeria.*

Introduction

Recently, there has been growing concern about the healthiness of diets globally, and consumers are revealing increasing interest in foods that minimise the risk of diseases for optimal health promotion, boost mental health and improve quality of life beyond foods with the traditional aim of hunger satisfaction or correction of nutrient deficiency (Green, 2014; Amoah et al., 2023). This is because poor-quality diets are highly correlated to chronic diseases like cancer, diabetes, heart disease, stroke, obesity and hypertension (Drewnowski et al., 2021), and have been identified as a phenomenon with the greatest threat to public health worldwide and changing lifestyles like poor nutrition and inadequate physical activity caused the epidemic of non-infectious diseases which lead to several health problems and even death (Plasek *et al*., 2020). According to Goetzke *et al*. (2014), it is important to prevent diseases considering the high costs of curative medicine. Therefore, it is pertinent to advocate for increasing the intake of foods with additional health benefits among households, which includes functional foods. The public interest in the concept of functional foods came into the limelight during the global awareness of the role foods could play in improving the health of human beings and was first established by the Japanese to introduce a legal category of foods with potential health benefits as part of national efforts to curbing the increasing cost of health care (Ohama *et al*., 2006). Functional food was invented in 1980 in Japan and was defined as enhanced food products that give a positive physiological action (Stanton *et al*., 2005). Functional foods could be natural or altered food products by adding or removing one or more components, reducing the risk of disease (Roberfroid, 1999). In 2012, a more consensus and acceptable definition was developed at the Functional Food Centre (FFC)'s 10th International Conference in Santa Barbara, CA. Functional foods were defined as ''Natural or processed foods that contain known or unknown biologically-active compounds; which in defined amounts provide a clinically proven and documented health benefit for the prevention, management, or treatment of chronic disease" (Martirosyan & Singh, 2015). Having noticed a deficiency in this definition, in 2014, at the 17th international conference jointly organised by the United States Department of Agriculture (USDA) and Agriculture Research Service (ARS). The definition of functional food was revisited in a Panel Discussion entitled "The Definition of Functional Foods and Bioactive Compounds". Functional foods were defined as "Natural or processed foods that contain known or unknown biologically-active compounds; which, in defined, effective, non-

toxic amounts, provide a clinically proven and documented health benefit for the prevention, management, or treatment of chronic disease" (Functional Food Centre, 2018). The amendment to this definition was in the amount of bioactive compound previously stated to be ´´defined amount´´ but changed to ´´defined effective non-toxic amount´´. This was necessary as the latter gave a more precise description for future use. Hence, the latter definition will be used in this study to select local functional foods established in the literature.

There are many health benefits of functional foods, ranging from their potential to boost the immune system to reduce the risk of cardiovascular problems, osteoporosis, obesity and cancer (some types), as well as to enhancing memory and physical condition (Bekoglu *et al*., 2016; Topolska *et al*., 2020). It generally improves the quality of life, prevents obesity and improves psychophysical and working ability (Jokić *et al*., 2016). It is acknowledged in the food market as a special category. It represents one of the most intense areas of innovation in food products globally (Đurović *et al*., 2020). It is more sought after in the hospitality market because it is essential for improving the quality of life, balancing and maintaining the maximum of body functions, maintaining health and reducing disease risk (Cvetković *et al*., 2016). Fortified products such as non-alcoholic beverages fortified with vitamin A, dairy products containing Lactobacillus fermentum ME-3, enriched products such as eggs enriched in omega-3 and vitamin E, natural foods such as cereals like oats and barley, which can be used as fermentable substrates for the growth of probiotic microorganism are examples of functional foods approved by European Food Safety Authority (Siro *et al*., 2008)

In Nigeria, some local/natural foods have potential as functional food sources. For instance, Acham *et al*. (2018) stated that Nigeria has abundant preservation of its own local functional food resources with massive potential of being a source of revenue to the people who are now becoming more conscious of their lifestyles or health status. In this study, local/natural functional foods are obtained from natural sources such as traditional food, fruits and vegetables. Some of these foods are edible mushrooms, tigernuts, soy milk, melon seed, bitter leaf, moringa, kunun-zaki, zobo, snail, edible insects, fura da nunu and garlic (Chanda *et al*., 2011; Akerele *et al*., 2016; Acham *et al*., 2018; Adenowo & Kazeem, 2020). These foods have been proven to have many health benefits. For instance, garlic has antimicrobial activity, anti-carcinogenic effects, antioxidant activity, ability to reduce cardiovascular diseases, improve immune functions, anti-diabetic activity and contains sulfide (Diallyl-sulfide, Diallyl-thiosulfinate, Allyl-methyl trisulfide) that help in detoxification of undesirable compounds, support the maintenance of heart, immune and digestive health; prebiotics (Inulin, Fructo-oligosaccharides, Polydextrose), that enhance maintenance of digestive health and calcium absorption; as well as selenium, which neutralises free radicals that may damage cells, and aids maintenance of immune and prostate health (Rahman, 2007). Frequent consumption of edible mushrooms can cure diabetes, breast cancer, prostate and high cholesterol levels (Okigbo & Nwatu, 2015). In fact, tigernut was referred to as natural functional food owing to its usefulness in treating indigestion and controlling flatulence, excessive thirst, diarrhoea, and dysentery treatment. It is also used in the prevention and treatment of coronary heart disease, obesity, diabetes, colon cancer and gastrointestinal disorders (Chevallier, 1996; Adejuyitan, 2011). Other local foods like fura (from millet) can prevent the incidence of gallstones in women (Chibuikem, 2015); edible insects like termite (M. nigeriensis) can be added to the diets of people suffering from high blood cholesterol content and probably at risk of cardiovascular disease because of its high desirable unsaturated fatty acid content and low saturated fatty acid (Alamu *et al*., 2013); snail is used in some part of Africa as native medicine to treat hypertension, whooping cough and asthma (Offiong *et al*., 2013). However, most of these foods are yet to be approved as functional food due to legislative or regulatory issues, especially by the European Union, which accepts products as functional foods if they are labelled and if the acclaimed health and nutritional benefits on their labels are guaranteed by law (Chanda *et al*., 2011). Although people are shifting attention to food with functional benefits to their health, studies have shown that preference has been given to natural/local functional food, that is, food whose functional components are inherent in the original products rather than added functional components (Siegrist *et al*., 2008; Kuster-Boluda & Vidal-Capilla, 2017).

Functional food is an emerging concept in Nigerian literature. Little is known empirically about the consumers´ awareness, preference and purchasing behaviour of these functional foods. For instance, some of the studies considered consumers´ attitudes and willingness to pay in Malaysia, Iran, Italy, Germany, China, Turkey, Spain (Salleh *et al*., 2015; Siegrist *et al*., 2015; Bekoglu *et al*., 2016; Küster-Boludaa & Vidal-Capilla, 2017; Mohammad *et al*., 2017; Palmieri *et al*., 2022). However, these studies pay little attention to local/natural functional foods. The available literature in Nigeria mainly selected one of these natural functional foods; for instance, Akerele et al. (2020) and Obayelu et al. (2015), among others, examined the health claim awareness and sources of the awareness for tiger nut and Consumers' willingness to pay for labelled and certified moringa products respectively. Also, Adetunji et al. (2022) focused on mushrooms as functional foods.

It is pertinent to examine consumers' preferences and purchasing behaviour of functional foods to provide information for farmers, food processing industries, and food marketers on the potential of these local foods as a source of income and to develop marketing strategies to capture potential customers in different parts of the world. In the long run, it will increase farmers' income, reduce poverty and promote good health and well-being, which are crucial parts of the sustainable Development Goals (SDGs) for 2030. Several researchers surveyed functional

foods and consumers' attitudes towards them. They observed that people purchase functional foods because they perceive they are healthier, safer and more convenient than other products (Nystrand & Olsen, 2020; Marina & Marija, 2014). Preference and purchasing behaviour of consumers could serve as sources of innovative ideas for novel foods (Grujić, 2024). To formulate and model products, producers must identify food properties that can benefit target consumers (Grujić & Odžaković, 2021). Consumers must widely accept functional foods. Other than its health properties, it must appeal to consumers. A healthy diet is popular when it includes tasty foods with acceptable sensory quality (Grujić et al., 2023). Food producers must improve the attractiveness of healthy food products for consumers' trust and acceptance (Lassale et al., 2019; Springfield et al., 2020). Producers must ensure they produce what consumers want in terms of quality and quantity. Consumer preference and purchase decisions cannot occur without knowledge of their motivations and utility derived. Information on consumer preference and purchasing behaviour of functional foods is essential to identify potential economic opportunities, promote food innovation and promote trade.

Materials and Methods

This research was conducted in the Ifo Local Government Area of Ogun State. Primary data were obtained through a questionnaire, and data collection was accomplished with the aid of a Kobotool box, which enabled us to access respondents physically and virtually. A multistage sampling technique was adopted to select respondents for the study. The first stage randomly selected 10 Community Development Committees (CDCs) in Ifo L.G.A. The second stage was the proportional random sampling of 30 Community Development Associations (CDAs) from the selected CDCs based on the size of the CDC. The third stage randomly selected 10 households from each selected CDA to give 300 households. However, only 240 households' responses were helpful in our analysis, giving an 80% response rate. The reason for this low response rate was that most of the responses gotten virtually did not complete the questionnaire compared to the respondents we interacted with physically.

Analytical Tools

Descriptive Statistics

We used descriptive statistics to describe the socio-economic characteristics of the respondents, the level and sources of awareness of urban households about the nutrition and health benefits of functional foods, and assess consumer preference and purchasing behaviour of selected functional foods.

Poisson Regression Model

The Poisson regression model was used to determine the factors influencing the purchasing behaviour of selected functional foods. The Poisson regression model was specified owing to its appropriateness in estimating count data as it is a non-linear regression model application of Poisson distribution. (Mensah-Bonsu et al., 2017). In this model, a scalar dependent variable is linked to independent variables. Following Chekol et al. (2022), this can be expressed as:

$$P(Y_i = y_{i,}\mu) = \frac{e^{-\mu_i}\mu^y}{y_i!}, \mu_i > 0, i = 1,2,3 \dots \dots$$

The equation can be specified as:

$$\mu = exp(\beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki})$$

Where y_i is the value of the count outcome occurring at a time with a mean parameter μ_i; μ is the mean and variance of the Poisson distribution, assumed to be a non-linear function of the explanatory variables; βs are the intercept and the coefficients of the (estimated parameters as maximum likelihood function) regressors; K represents the number of regressors.

The dependent variable (y) is the frequency of purchase of functional foods per week. The analysis was done separately for each selected functional food.

The explanatory variables used in the study are:

X_1 = Awareness of health benefits (Dummy: 1 if yes; 0, otherwise)
X = Age of household head (Years),
X_3 = Sex of household head (Dummy: 1 if male; 0, otherwise),
X_4 = Marital status (Dummy: 1 if married; 0, otherwise), Households size (Number)
X_5 = Education (Years spent in school),
X_6 = Major occupation of spouse (Dummy: 1 if civil service; 0, otherwise),
X_7 = Major occupation of household head (Dummy: 1 if civil service; 0, otherwise),
X_8 = Monthly income of spouse (Naira),
X_9 = Monthly income of household head (Naira),
X_{10} = Monthly garlic expenditure (Naira),
X_{11} = Monthly ginger expenditure (Naira),
X_{12} = Monthly tigernut expenditure (Naira),
X_{13} = Monthly turmeric expenditure (Naira)
X_{14} = Monthly moringa expenditure (Naira)

Results and Discussion

Socioeconomic Characteristics of Households.

The mean age of household heads in the study area was approximately 53 years, which means that the majority (about 57%) were aged above 50 years. The majority (app. 85%) of household heads were male, as expected from typical African culture, where males are expected to head households and provide basic needs for them. Most (about 85%) household heads were married, which may have substantially affected their consumption pattern compared to other types of households. The average household size was 4, and the majority (about 56%) of households had less than 4 members, close to the average size of 5 from Akerele *et al. (2020)*. There was a high level of education among the households in the study area, where the largest share of the respondents (about 44%) had a bachelor's degree or higher national diploma. In comparison, only about 2% had no formal education, which was contrary to the finding of Akerele et al. (2020), where NCE and National Diploma were the highest levels of education. The major occupation of more than half of the household heads was civil service, followed by trading, while the majority (about 54%) of their spouses were traders.

Table 1: Socioeconomic Characteristics of Households.

	Frequency	Percentage	Mean
Age of household head			
≤ 30	6	2.50	52.62
31 – 50	97	40.41	
Above 50	136	57.08	
Sex of household head			
Female	35	14.58	
Male	205	85.42	
Marital status			
Married	205	85.42	
Single	15	6.25	
Widowed	11	4.58	
Divorced	8	3.33	
Separated	1	0.42	
Religion			
Christianity	130	54.17	
Islam	108	45.00	
Traditional	2	0.83	
Household size			
≤ 4	134	55.83	4.46
5 – 8	103	42.92	
9 – 12	2	0.83	
Above 12	1	0.42	
Education			
BSc/HND	105	43.75	
Masters/PhD	16	6.67	
ND/NCE	77	32.08	
Primary Education	2	0.83	
Secondary Education	36	15.00	
No Formal Education	4	1.67	
Major occupation of household head			
Civil Service	122	50.83	
Artisan	40	16.67	
Farming	11	4.58	
Trading	67	27.92	
Major occupation of spouse			
Civil Service	47	20.03	
Artisan	54	22.50	
Farming	2	0.83	
Trading	131	54.58	
Others	6	2.50	
Total	**240**	**100**	

Source: Field Survey, 2023

Distribution of Households' Income and Food Expenditure.

The average monthly income of the household head was about 88,000 naira, meaning that the most significant proportion (about 45%) earned between 50,000 and 100,000 naira monthly. On the other hand, the majority (about 69%) of the spouses earned 50,000 naira or less per month. On average, about 47,000 naira was spent on food by the households in the study area, while about 100,000 naira was spent on non-food items. This implies that the majority (about 87%) of the households spent less than 50,000 on food, while more than 50% spent between 50,000 and 100,000 on non-food items.

Table 2: Distribution of Households' Monthly Income and Expenditure.

	Frequency	Percentage	Mean
Income of Household Head			
≤ 50000	91	37.92	87793.16
50000 – 100000	108	45.00	
100001 – 200000	26	10.83	
above 200000	15	6.25	
Income of Spouse			
≤ 50000	166	69.17	56797.43
50001 – 100000	59	24.58	
100001 – 200000	12	5.00	
above 200000	3	1.25	
Other Income			
≤ 50000	212	88.33	33792.89
50001 – 100000	24	10.00	
100001 – 200000	4	1.67	
Food Expenditure			
≤ 50000	210	87.5	47020.87
50001 – 100000	28	11.67	
Above 100000	2	0.84	
Non-Food Expenditure			
≤ 50000	68	28.34	102701.10
50001 – 100000	124	51.67	
Above 100000	48	20.00	
Total	240	100	

Source: Field Survey, 2023

Level and Sources of Awareness About the Health Benefits of Functional Foods

Most households knew the health benefits of all the selected functional foods (moringa, garlic, ginger, tigernut, and turmeric). This awareness could influence their consumption and dietary choices. The level of awareness varies across functional foods; the highest awareness level was reported for ginger, with about 99% of the respondents, followed by garlic (about 97%), tiger nut (app. 93%), and turmeric (app. 78%). Moringa had the lowest awareness level with about 56% of respondents. This means that almost all the respondents knew the health benefits of ginger, garlic, and tigernut. This is crucial for their preference and consumption among households.

The data also give insights into how individuals in the surveyed population gain awareness about dietary choices. Family and friends (43.75%) and health professionals (35.83%) were the two most common sources of awareness about functional health benefits. This indicates that personal relationships and healthcare experts play significant roles in propagating the healthiness of diets. Books or publications (9.58%), seminars or workshops on nutrition (3.75%), and radio/television (4.59%) were also sources of awareness to some individuals, although to a lesser extent. Only about 2% of the respondents got information on the health benefits of these foods through newspapers. This might be due to low publications on the health benefits of foods in newspapers or that most respondents have not acquainted themselves with the newspaper. In summary, this result showed a high level of awareness about the healthiness of functional foods. It emphasised the significant impact of family, friends and healthcare professionals in achieving such a high level of awareness. The implication is that family, friends, and health workers can be important avenues for shaping urban households' dietary choices and consumption patterns to be healthy and sustainable.

Frequency of Purchase of Functional Foods Per Week

The result of the weekly purchase of functional foods is presented in Table 4. Ginger is the most frequently purchased functional food among the selected foods, and it was purchased on average about 1.48 times per week. This was followed by tigernut and garlic, which were purchased about 1.36 and 1.26 on average, respectively, per week. The high purchase frequency of ginger and garlic might be because most households use them as spices in food and soup. Also, tigernuts require little or no processing compared to others before eating, and most people eat them as snacks, which justifies their higher purchase frequency. Turmeric and moringa were the least purchased

functional foods, with an average purchase frequency of 0.97 and 0.98, respectively. Unlike garlic and ginger, these two functional foods are used primarily for medicinal purposes among those aware of their functionality; consequently, if we assume that purchases equal consumption, this result shows that the most frequently consumed functional foods were ginger, garlic, and tigernuts due to their inclusion as spices in foods and minimum processing requirements.

Table 3: Level and Sources of Awareness about the Health Benefits of Functional Foods

Level of Awareness	Frequency	Percent
Moringa		
No	105	43.75
Yes	135	56.25
Garlic		
No	8	3.33
Yes	232	96.67
Ginger		
No	3	1.25
Yes	237	98.75
Tiger nut		
No	16	6.67
Yes	224	93.33
Tumeric		
No	52	21.67
Yes	188	78.33
Total	**240**	**100.00**
Sources of Awareness		
Books or publications	23	9.58
Family and friends	105	43.75
Health professionals	86	35.83
Newspapers	5	2.08
Radio/Television	11	3.59
seminars or workshops on nutrition	10	4.17
Total	240	100.00

Source: Field Survey, 2023.

Table 4: Frequency of Purchase of Functional Foods Per Week

Moringa	Frequency	Percentage	Mean
≤ 1	215	89.58	0.98
2 – 3	18	7.50	
Above 3	7	2.92	
Garlic			
≤ 1	196	81.67	1.29
2 – 3	32	13.33	
Above 3	12	5.00	
Ginger			
≤ 1	189	78.75	1.48
2 – 3	33	13.75	
Above 3	18	7.50	
Tigernut			
≤ 1	190	79.17	1.36
2 – 3	35	14.58	
Above 3	15	6.25	
Turmeric			
≤ 1	223	92.92	0.97
2 – 3	12	5.00	
Above 3	5	2.08	

Source: Field Survey, 2023

Attributes Considered When Selecting Functional Foods

When choosing preferred functional foods, consumers consider some attributes that later inhibit or improve their purchasing behaviour. These attributes include taste, flavour, nutrient content, health benefits and price. The respondents were asked to select the most important attribute before selecting functional foods. According to their responses, nutritional value was the most important attribute, with more than 70% of the respondents' affirmation. This was followed by flavour, health benefits and taste, as indicated by about 66%, 58% and 57% of respondents. Price was the least considered attribute, as it was chosen by only about 13% of the respondents. This showed that respondents valued functional nutritional and health attributes over their prices. Consequently, emphasis should be placed on the quality of functional foods when policy regarding their consumption is formulated.

Table 5: Attributes Considered in Selecting Functional Foods

Attributes	% of an affirmative response
Taste	56.67
Flavour	66.25
Nutritional value	70.83
Health benefits	57.92
Price	13.33

Source: Field Survey, 2023

Attributes Considered When Purchasing Functional Foods

We also inquire about the attributes that influence the purchase of functional foods. Some of the factors frequently mentioned in the literature were presented to the respondents, including price, availability, taste, quality, convenience, and security, among others, to rank based on their effects on the purchase. The result showed that price, availability and taste were ranked first, second and third, respectively, as the factors with the most significant impact on purchasing functional foods. This is understandable based on the premise of demand theory. It might also be a result of the economic status of most of the respondents. The implication is that policy on price regulation, increasing production and value addition to functional foods should be a priority to increase the consumption of these foods among consumers.

Table 6: Attributes Considered when Purchasing of Functional Foods

Factors	Score	Rank
Price	1119	1st
Availability	1087	2nd
Taste	1077	3rd
Convenience	1037	4th
Familiarity and security	1018	5th
Trust products	957	6th
Better quality	949	7th
Product healthy options	907	8th
Attractive package	821	9th
Information given on the label	798	10th
Personal health issues	712	11th
Recommended by health professionals	703	12th

Source: field survey, 2023

Point of Purchase of Functional Foods

The point of purchase is necessary for targeting policy intervention. Identifying the point of purchase of most respondents would enlighten policymakers on how to improve the marketing of these products and pricing regulation to enhance their consumption. According to this result, the purchase points of the selected functional foods vary slightly. While most of the functional foods (four out of five, that is, garlic, ginger, turmeric and moringa) were purchased at the local markets by the majority (more than 50%) of the respondents, tigernut was purchased from roadside vendors by the most (about 45%) of the respondents. Aside from local markets, some respondents also purchased from supermarkets, making it the second preferred point of purchase for garlic, ginger, turmeric and moringa. The implication is that to facilitate the consumption of functional foods, the government and non-governmental organisations should target local markets when formulating policies regarding demand, supply and price regulation for functional foods to improve their consumption.

Table 7: Point of Purchase of Functional Foods

Tigernut	Frequency	Percentage
Local markets	88	36.67
Roadside vendors	107	44.58
Supermarkets	41	17.08
Others	4	1.67
Garlic		
Local markets	143	59.58
Roadside vendors	44	18.33
Supermarkets	50	20.83
Others	3	1.25
Moringa		
Local markets	122	50.83
Roadside vendors	38	15.83
Supermarkets	74	30.83
Others	6	2.5
Turmeric		
Local markets	118	49.17
Roadside vendors	38	15.83
Supermarkets	70	29.17
Others	14	5.83
Ginger		
Local markets	154	64.17
Roadside vendors	37	15.42
Supermarkets	46	19.17
Others	3	1.25
Observation	240	100.0

Source: Field Survey, 2023

Factors Considered When Choosing Where to Purchase Functional Foods

Most respondents ranked safety, freshness, and brand reputation as the most important factors for choosing the supermarket to purchase functional foods. Purchasing by the roadside was motivated mainly by safety, which ranked first, followed by price and freshness. In contrast, the highest choice factors for local market purchase were safety, variety and price. Based on this, safety was the most important factor consumers considered when choosing where to buy functional products, followed by freshness prices. This implies that to increase the consumption of functional foods, policymakers and stakeholders in agriculture, food system, and health should monitor all purchase points to improve the safety of goods so that consumers can purchase these items at any purchasing point closer to them without worrying about food safety.

Table 8: Factors that Determine the Choice of Point of Purchase

	Supermarket		**Roadside**		**Local markets**	
Attribute	Score	Rank	Score	Rank	Score	Rank
Price	969	5th	1101	2nd	1101	3rd
Freshness	1164	2nd	1092	3rd	1101	3rd
Safety	1184	1st	1123	1st	1118	1st
Distance	766	6th	1002	5th	1058	4th
Variety	1106	4th	1076	4th	1102	2nd
brand reputation	1135	3rd	665	6th	664	5th

Source: Field Survey, 2023

Factors Influencing the Purchasing Behaviour of Selected Functional Foods

Table 9 shows the factors influencing the purchasing behaviour of selected functional foods (moringa, garlic, ginger, tigernut, and turmeric) among households. The frequency of purchase was used as a proxy for purchasing behaviour following Adeoye et al. (2016). The frequency of moringa purchases was significantly affected by the household head's and spouse's monthly income, with negative and positive effects, respectively. This implies that while the monthly income of the household head inhibits its purchase frequency, the spouse's monthly income enhances it. The expenditure on tigernut also positively affected the frequency of purchase of moringa. This means

that the frequency of moringa purchases increases with tigernut expenditure. Also, married household heads had a higher frequency of purchasing moringa than others (single, divorced, and separated).

The major occupation of the household head (using civil service as a reference) and ginger expenditure had negative and positive significant effects on ginger purchasing behaviour, respectively. This means that civil servant households purchased ginger less frequently. Also, ginger purchasing frequency increases with expenditure.

The purchasing behaviour of tigernut is significantly influenced positively by marital status (ρ10%), education (5%) of household heads and tigernut expenditure (1%), and negatively by the occupation of household heads (10%). This implies that married household heads with a high level of education had a higher frequency of tigernut purchases, and the civil servant household had a lower frequency of purchasing tigernut. The frequency of purchase of tigernut increases with tigernut expenditure. This finding is consistent with Akerele et al. (2020), who state that a higher level of education enhances the consumption of tigernuts.

Table 9: Factors Influencing the Purchasing Behaviour of Selected Functional Foods

	Moringa		Garlic		Ginger		Tigernut		Turmeric	
Frequency of purchase	Coef. (Std.err.)	P>z	Coef. (Std.err)	P>z	Coef. (Std.err.)	P>z	Coef (Std.err.)	P>z	Coef (Std.err.)	P>z
Awareness	0.240 (0.155)	0.121	-0.165 (0.334)	0.622	0.855 (0.719)	0.235	0.145 (0.252)	0.565	0.648*** (0.218)	0.003
Age of household head	0.000 (0.006)	0.947	-0.006 (0.006)	0.248	-0.002 (0.005)	0.651	-0.002 (0.006)	0.774	-0.012* (0.006)	0.058
Sex household head	-0.080 (0.214)	0.707	-0.163 (0.178)	0.361	-0.085 (0.173)	0.621	0.182 (0.194)	0.348	-0.151 (0.205)	0.459
Household size	0.028 (0.027)	0.306	0.009 (0.027)	0.732	-0.005 (0.028)	0.856	-0.022 (0.034)	0.508	0.040** (0.020)	0.050
Marital status of household head	0.270* (0.159)	0.090	0.116 (0.132)	0.379	0.176 (0.124)	0.155	0.224* (0.131)	0.087	-0.025 (0.154)	0.870
Education of household head	0.011 (0.028)	0.695	0.026 (0.026)	0.306	0.029 (0.024)	0.221	0.051** (0.026)	0.047	0.046 (0.031)	0.132
Major occupation spouse	-0.057 (0.194)	0.771	0.047 (0.166)	0.778	0.020 (0.157)	0.897	0.114 (0.159)	0.472	-0.043 (0.194)	0.826
Major occupation of household head	0.170 (0.176)	0.334	-0.025 (0.149)	0.866	-0.237* (0.139)	0.089	-0.249* (0.146)	0.088	-0.263 (0.169)	0.121
Monthly income of spouse	3x10^6** (0.000)	0.046	0.000 (0.000)	0.819	0.000 (0.000)	0.518	0.000 (0.000)	0.180	4.3x10^6*** (0.000)	0.008
Monthly income of household head	-4.6x10^7*** (0.000)	0.003	0.000 (0.000)	0.572	0.000 (0.000)	0.564	0.000 (0.000)	0.101	-4.5x10^6*** (0.000)	0.002
Garlic expenditure	0.000 (0.000)	0.194	0.000 (0.000)	0.785	0.000 (0.000)	0.970	0.000 (0.000)	0.623	-4.3x10^4*** (0.000)	0.007
Ginger expenditure	0.000 (0.000)	0.235	0.000 (0.000)	0.313	0.000** (0.000)	0.050	0.000 (0.000)	0.238	-2.7x10^4* (0.000)	0.075
Tigernut expenditure	1.4x10^4** (0.000)	0.020	0.000 (0.000)	0.107	0.000 (0.000)	0.117	1.6x10^4*** (0.000)	0.000	0.000 (0.000)	0.770
Turmeric expenditure	0.000 (0.000)	0.418	0.000 (0.000)	0.293	0.000 (0.000)	0.423	0.000 (0.000)	0.416	2.4x10^4*** (0.000)	0.003
Moringa expenditure	0.000 (0.000)	0.196	0.000 (0.000)	0.761	0.000 (0.000)	0.276	0.000 (0.000)	0.638	0.000 (0.000)	0.295
Constant	-0.691 (0.518)	0.182	0.240 (0.585)	0.681	-0.968 (0.864)	0.263	-0.753 (0.529)	0.155	-0.512 0.564)	0.364
Number of observations	240		240		240		240		240	
LR chi2(15)	69.420		36.040		49.810		58.650		82.110	
Prob > chi2	0.000		0.002		0.000		0.000		0.000	
Pseudo R2	0.118		0.058		0.070		0.086		0.139	
Log likelihood	-259.282		-295.135		-330.132		-313.381		-255.385	

Source: Field Survey, 2023

The purchasing behaviour of turmeric is positively influenced by awareness of its nutrition and health benefits, household size, the income of the spouse, and turmeric expenditure. The implication is that awareness of nutrition and health benefits enhances the purchasing of turmeric. This is similar to the finding of Akerele et al. (2017) that awareness positively influences the consumption of some foods known with specific health claims in Nigeria. Also, larger households with higher spouse income had a higher purchase frequency. However, the age and income of household heads and garlic and ginger expenditure negatively affected its purchasing. The frequency of purchase increases with an increasing level of awareness, household size, the income of the spouse and the amount spent on turmeric per week. At the same time, it decreases as the age and income of household heads increase. The higher the garlic and ginger expenditure, the lower the purchase frequency of turmeric. Contrarily, Ong et al. (2014) affirmed that age positively correlated with the purchase frequency of functional foods. Also, Sekinat et al. (2024) stated that as people's age increases, social factors have more impact on their purchase decisions toward functional foods.

Conclusion

The demographic and socioeconomic characteristics of the surveyed population provide valuable insights into the diversity and occupation patterns within the community. Income and expenditure patterns indicate varying economic conditions, with a substantial portion of the population falling into the average income categories. Sources of awareness highlight the significance of family, friends, and health professionals in disseminating nutrition and health-related information. The roadside vendors and local markets were the major suppliers of functional foods to the households. Price and availability were the most crucial attributes considered when purchasing functional foods. Age, marital status and income were the determinants of purchasing behaviour of functional foods.

Recommendations

To enhance the consumption of functional foods, it is necessary to improve their availability and ensure that they are accessible at lower, regulated prices, especially among local market and roadside vendors. Since age and income were important determinants of purchasing behaviour, increasing the minimum wage will enhance purchasing functional foods since most respondents were civil servants. For effective policy regarding functional foods, there is a need to consider age differences since it is an important determinant of functional food purchasing behaviour. Future research should consider a larger sample size that covers a wider geographical location to enhance the generalizability of the findings. It may also consider diversity in socioeconomic characteristics when analysing data on functional food consumption and purchasing behaviour.

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Antimicrobial Potential of Prickly Pear (Opuntia ficus-indica) Seed Oil and Grain Extracts

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Abstract

The prickly pear (*Opuntia ficus-indica*) is a succulent plant belonging to the cactus family. It is a highly nutritious and refreshing fruit, valued for its seeds and oil. This study aims to evaluate the antibacterial and antifungal activity of oil extracted from prickly pear seeds (from the Bordj Bou Arréridj region) and the acetone extract of spontaneous grains against 15 microbial strains (bacteria and fungi). The samples were extracted separately using distilled water and 70% acetone to obtain a dry extract, which was then stored at 4°C until testing. The antimicrobial activity was assessed using the agar diffusion method (well diffusion technique), measuring the diameters of inhibition zones. The results indicate that four bacterial strains and six fungal strains, including two yeasts, were sensitive to the dry extract. For the oil extract, two bacterial strains and five fungal strains, including two yeasts, exhibited sensitivity. Both extracts demonstrated strong antimicrobial activity, particularly against yeasts and Gram-positive bacteria, confirming the antimicrobial potential of *Opuntia ficus-indica*.

Keywords: *Opuntia ficus-indica*, seed oil, antibacterial activity, antifungal activit

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A Comprehensive Study on Heat Balance Analyses in Grain Warehouses During the Winter Season: The Case of Konya Province

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Abstract

The storage of agricultural products such as grains, which are of strategic importance for food security and agricultural sustainability, has become an increasingly critical issue worldwide. In this context, preserving the quality of stored products with minimal loss is only possible by precisely controlling the environmental conditions within the warehouse. This study was conducted to reveal how vary depending the positive or negative flow conditions between heat losses caused by structural elements and ventilation, as well as the heat generated by the metabolic activities of the products, on the building materials used and the type of products in storage structures with different constructions during the winter season. As a result of material-based analyses, it has been determined that the thermal conductivity value of 2.62 kcal/m²h°C measured in steel warehouses is statistically significantly higher than the value of 1.69 kcal/m²h°C in reinforced concrete warehouses. Despite the higher minimum ventilation rate requirements in concrete silos (barley: 19, wheat: 24, corn: 74 $m^3 \cdot h^{-1} \cdot ton^{-1}$), steel silos (barley: 18, wheat: 23, corn: 73 $m^3 \cdot h^{-1} \cdot ton^{-1}$) exhibited higher ventilation efficiency for all products (34%, 22%, 8%). In contrast, the efficiency values in concrete silos (17%, 11%, 4%) remained relatively low. The heat balance analyses conducted during the winter months in different storage materials (concrete/steel) have clearly revealed product-based ventilation differences. These findings clearly demonstrate that when designing grain storage systems, not only structural factors but also parameters such as storage capacity, product type, the presence of ventilation systems, and the thermal conductivity levels of structural elements must be considered. It has been concluded that storing grains with a high respiration rate (such as corn) in steel warehouses, which provide higher ventilation performance, would be more suitable. The results of this study prove that the selection of materials used in storage structures plays a critical role in the energy efficiency of storage systems.

Key Words: *Thermal conductivity, Heat balance, Ventilation efficiency, Concrete and steel warehouses, Grain storage.*

Kış Mevsiminde Hububat Depolarında Isı Dengesi Analizleri Üzerine Kapsamlı Bir Araştırma: Konya İli Örneği

Özet

Gıda güvenliği ve tarımsal sürdürülebilirlik açısından stratejik öneme sahip olan hububat gibi tarımsal ürünlerin depolanması, dünyada giderek kritik bir konu haline gelmiştir. Bu bağlamda, depolanan ürünlerin kalitesinin minimum kayıpla korunabilmesi ancak depo içi çevre koşullarının hassas bir şekilde kontrol edilebilmesiyle mümkündür. Bu çalışma, farklı konstrüksiyona sahip depolama yapılarında, kış mevsimi boyunca yapı elemanları ve havalandırmadan kaynaklı ısı kayıpları ile ürünlerin metabolik faaliyetleri sonucu açığa çıkan ısı miktarları arasındaki pozitif ya da negatif yönlü akış koşullarının; kullanılan yapı malzemeleri ve ürün çeşidine göre nasıl değişkenlik gösterdiğini ortaya koymak amacıyla yürütülmüştür. Malzeme bazlı yapılan analizler sonucunda, çelik depolarda hesaplanan 2.62 kcal/m²h°C'lik ısıl iletkenlik değerinin, betonarme depolardaki 1.69 kcal/m²h°C değerinden istatistiksel olarak anlamlı derecede yüksek olduğu belirlenmiştir. Beton silolardaki yüksek minimum havalandırma debi gereksinimlerine (arpa: 19, buğday: 24, mısır: 74 $m^3 \cdot h^{-1} \cdot ton^{-1}$) karşın, çelik silolar (arpa: 18, buğday: 23, mısır: 73 $m^3 \cdot h^{-1} \cdot ton^{-1}$) tüm ürünlerde daha yüksek havalandırma verimliliği (%34, %22, %8) sergilemiş, beton silolardaki verimlilik değerleri ise (%17, %11, %4) nispeten düşük seviyelerde kalmıştır. Farklı depo malzemelerinde (beton/çelik) kış aylarında yürütülen ısı dengesi analizleri, ürün bazlı havalandırma farklılıklarını net biçimde ortaya koymuştur. Bu bulgular, tahıl depolama sistemleri tasarlanırken sadece yapısal değil, aynı zamanda depolama kapasitesi, ürün çeşidi, havalandırma sistemlerinin varlığı ve yapı elemanlarının termal ısıl iletim düzeyleri gibi parametrelerin de dikkate alınması gerektiğini açıkça göstermektedir. Özellikle yüksek solunum hızına sahip olan tahılların (örneğin mısır) yüksek havalandırma performansı sağlayan çelik depolarda depolanmasının daha uygun olacağı sonucuna varılmıştır. Bu çalışmadan elde edilen sonuçlar, depolama yapılarında kullanılacak malzeme seçiminin depolama sistemlerinin enerji verimliliği üzerinde kritik bir rol oynadığını kanıtlamaktadır.

Anahtar Kelimeler: *Termal iletkenlik, Isı dengesi, Havalandırma verimliliği, Beton ve çelik depolar, Hububat depolama.*

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Restoring Agroecosystem Biodiversity: The Role of Regenerative Agriculture in Reversing Monoculture-Induced Declines

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Abstract

The modern global food system is increasingly fragile, a consequence of the sweeping agricultural transformations initiated during the Green Revolution of the 1940s. While the Green Revolution introduced high-yielding crop varieties (HYVs), chemical fertilizers, pesticides, and intensive irrigation, these advancements came at a cost: a significant loss of crop biodiversity, soil degradation, and increased vulnerability of food systems to climate change and disease outbreaks. The Food and Agriculture Organization (FAO) estimates that 75% of global crop diversity was lost between 1900 and 2000. This paper examines the unintended consequences of the Green Revolution on food security and biodiversity while exploring regenerative agriculture as a viable solution to correct these damages. Regenerative farming practices, including crop diversification, organic soil amendments, reduced chemical inputs, and agroecological approaches, have demonstrated potential in restoring soil fertility and increasing ecosystem resilience. By transitioning from an extractive, yield-maximizing agricultural model to a regenerative one, it is possible to address food production challenges in a sustainable manner. This paper also highlights the need for policy shifts, economic incentives, and scientific research to support the widespread adoption of regenerative agriculture, ensuring a resilient global food system for the future.

Keywords: *Green Revolution, regenerative agriculture, crop biodiversity, food security, nutrient density, industrial agriculture, sustainability, malnutrition.*

1.0 Introduction

Biodiversity refers to all species of plants, animals and micro-organisms existing and interacting within an ecosystem (Vandermeer and Perfecto, 1995). Natural biodiversity has provided the foundation for all agricultural plants and animals. The entire range of the domestic crops used in world agriculture is derived from wild species that have been modified through domestication, selective breeding and hybridization. Most remaining world centers of diversity contain populations of variable and adaptable landraces as well as wild and weedy relatives of crops, all of which provide valuable genetic resources for crop improvement (Harlan, 1975).

According to Clergue (2005), biodiversity is a very complex issue. In agroecosystems, it serves three basic functions: genetic, agricultural, and ecological functions. The first function of biodiversity involves maintaining species gene pool, in particular, the endangered ones. The second function, connected with agricultural activity, contains increasing the resistance of agroecosystems to abiotic and biotic stresses, as well as maintaining their productive role. Biodiversity has also ecological functions, for example, creating habitats with different flora and fauna species that have specific significance in agroecosystems. The issue of widespread species decline and ecosystem degradation was formally highlighted in 1992 with the creation of the Convention on Biological Diversity (CBD) during the inaugural Earth Summit held by the United Nations in Rio de Janeiro, Brazil.

The loss of biological diversity is one of the most important problems of the world and a threat to our civilization. The destruction of primary ecosystems, intensive farming, urbanization, and also infrastructure development cause depletion and weakening of the stability of ecosystems. Agroecosystems are the most at risk of losing biological diversity (TEEB, 2008). During the last decades, worldwide losses of biodiversity have occurred at an unprecedented scale and agricultural intensification has been a major driver of this global change (Matson *et al*., 1997).

Since the 1900s, some 75-percent of plant genetic diversity has been lost as farmers worldwide have left their multiple local varieties and landraces for genetically uniform, high-yielding varieties. 30-percent of livestock breeds are at risk of extinction; six breeds are lost each month. Today, 75-percent of the world's food is generated from only 12 plants and five animal species. Of the 4-percent of the 250-000 to 300-000 known edible plant species, only 150 to 200 are used by humans. Only three-rice, maize and wheat - contribute nearly 60-percent of calories and proteins obtained by humans from plants. Animals provide some 30-percent of human requirements

for food and agriculture and 12-percent of the world's population live almost entirely on products from ruminants (FAO, 1999).

The net result of biodiversity simplification for agricultural purposes is an artificial ecosystem that requires constant human intervention, whereas in natural ecosystems the internal regulation of function is a product of plant biodiversity through flows of energy and nutrients, and this form of control is progressively lost under agricultural intensification (Swift and Anderson, 1993). Commercial seed-bed preparation and mechanized planting replace natural methods of seed dispersal; chemical pesticides replace natural controls on populations of weeds, insects, and pathogens; and genetic manipulation replaces natural processes of plant evolution and selection. Even decomposition is altered because plant growth is harvested and soil fertility maintained, not through nutrient recycling, but with fertilizers (Cox and Atkins, 1979).

Thus, modern agricultural systems have become productive but only by being highly dependent on external inputs. A growing number of scientists, farmers and the general public fear for the long-term sustainability of such highly input-dependent and ecologically simplified food production systems. Questions are being raised about the growing dependence of modern farming on non-renewable resources, the loss of biodiversity, the loss of land through soil erosion and the heavy reliance on chemical fertilizers and pesticides. Farm chemicals are questioned on grounds of cost but their widespread use also has implications for human and animal health, food quality and safety and environmental quality. The commercial agricultural sectors of developing countries suffer from similar problems but the greater challenge for them is to determine new ways to increase small farm productivity that not only benefit the rural poor under marginal agricultural conditions (hillsides, rainfed and marginal soils), but also conserve and regenerate the resource base (Altieri, 1995).

The significant decline in agroecosystem biodiversity can be largely attributed to the Green Revolution, which catalyzed the widespread adoption of high-yielding crop varieties and intensive monoculture farming systems. This transformation prioritized productivity and uniformity over ecological diversity, leading to habitat simplification, reduction in genetic variability, and disruption of ecological interactions essential for resilient agroecosystems. Promoting functional biodiversity within agroecosystems represents a fundamental ecological approach to achieving sustainable agricultural production. To illustrate this concept, this paper examines how regenerative farming practices can help counteract the negative impacts caused by monoculture-driven biodiversity loss.

2.0 Monoculture, Ecological Impact and Agroecosystem Decline

Monoculture/solely crop production farms are the farming types by which farmers grow only crops, both annual crops/trees and field crops, such as wheat, corn, rice, rapeseed, sugar cane, and cotton. Monoculture is widely used in industrial farming systems, including conventional and organic farming, and has allowed increased efficiency in planting and harvest. Continuous monoculture, or "monocropping" where the same species is grown year after year, can lead to unsustainable environments such as building up disease pressure and reducing particular nutrients in the soil. Under certain circumstances, monocropping can lead to deforestation. The practice has also been criticized for its environmental impacts, one of the major being soil degradation due to non-rotational cropping. Crop rotation is the practice of changing the types of crops in a farmland from year to year, which improves soil health and quality, whereas monocropping has been implicated in the loss of nutrients from the soil (Bennett *et al*., 2012).

Monoculture is the annual production of the same plant species on a farm, for one or more years (Andres *et al*., 2016; Utomo *et al*., 2016). It is a commercial mode of production that has been predominant in recent decades and has largely integrated food market systems, as it is mass-produced (Woźniak, 2020).

From an economic viewpoint, larger or single-component production with mechanical- or technological-dependent system seems more practical. By cultivating the same species in a huge land area, farmers can maximize their profit by mass production via a single operation through unique growing/farming practices including planting, maintaining (including pest control), and harvesting with similar resources. This helps result in a greater yield at a lower cost. In addition, farmers can pick the best monoculture crops to grow considering the local climate and soil conditions. Further, it is much easier and straightforward to cultivate one kind of crop or breed one type of livestock in terms of the knowledge and experience needed to do it successfully (Salaheen & Biswas, 2019).

Monoculture farming has several disadvantages due to the ability to produce a larger volume of affordable products with less investment. Monoculture farming cultivates a single crop in an intensive manner and on a very large scale, such as current practices in the United States in which corn, wheat, soybeans, cotton, and rice are commonly grown. However, growing the same crops year after year can deplete the soil of appropriate nutrients or humus that play key roles in soil fertility. In some cases, monocultures are more susceptible to certain weeds and pests, which means that farmers will depend vastly on pesticides to save their crops, which may have environmental impacts (Salaheen & Biswas, 2019).

For example, Zhao *et al*. (2018) have currently showed that coffee monoculture, in the long term, decreased soil pH and organic matter content, while it increased soil salinity, which severely inhibited the growth of coffee plants and therefore affected its yield. The richness of soil bacteria and of fungal communities also declined with

continued coffee cultivation (Zhao *et al*., 2018). Similarly, Xiong *et al*. (2015) have demonstrated that continuous and long-term cultivation of black pepper resulted in a significant decrease in organic matter content, soil pH, and enzyme activities. These led to a decline in the abundance of soil bacteria, hence 454 pyrosequencing analyzes of 16S rRNA genes revealed that acidobacteria and proteobacteria were the major phyla that dominated 73% of the soil around black pepper plants. Similarly, the relative abundance of the Bacteroides and firmicutes phyla was depleted with continuous cultivation, and at the genus level, the abundance of Pseudomonas decreased significantly after 21 years of monoculture (Xiong, Li, *et al*., 2015).

Further, Liu *et al*. (2014) also confirmed this finding and have revealed that soil bacterial communities formed by potato monoculture have increased soil incidence of Fusarium wilt disease which impacted the performance of this crop. When a crop is grown as a monoculture, the microbial community is instantly exposed to the roots of that plant, selecting certain groups of microorganisms, namely soil pathogens, which are responsible for debilitating the yield of that crop (Cook, 2006).

Several studies on the monoculture of soybeans (Bai *et al*., 2015), melon (Soriano-Martín *et al*., 2006), bananas (Chen *et al*., 2013), and apples (Mazzola & Manici, 2012). With regard to yield and plant biomass, it turned out that the latter dropped significantly, in monoculture. This was supported by the study conducted by Zhao *et al*. (2018), which showed that shoots and dry weight of coffee decreased significantly with increasing years of monoculture. Similarly, Strom *et al*. (2020) found that soybean did not have a high yield after planting it directly after five years of continuous maize cultivation.

Further, continuous cultivation of black pepper severely inhibits its growth (Xiong *et al*., 2015). Continuous cultivation or monoculture can lead to an unhealthy and unsustainable environment, easily developing diseases and draining the soil from its nutrients, which is responsible for debilitating yields (Salaheen & Biswas, 2019).

The crops grown in the genetically homogeneous monocultures that characterize industrial farming are neither able to feed the world's expanding population nor resilient to the more frequent and destructive climate extremes (Altieri *et al*., 2015; Reza & Sabau, 2022). For instance, Wright *et al*. (2017) found that crop species grown in plots with higher biodiversity were, on average, less adversely affected by flooding, and the plants with higher system leaf area and higher root system performed better.

Furthermore, plots with mixed crops had higher soil porosity, which positively impacted plant performance. The negative impact of flooding on the performance of monocrops is primarily due to limited gas exchange due to slower gas diffusion in water compared to air, and low light intensity in turbid floodwaters, thereby causing an energy and carbohydrate deficit (Sasidharan & Voesenek, 2015), inhibiting plant growth, and eventually its survival (Mommer & Visser, 2005; Nguyen *et al*., 2018; Zhou *et al*., 2020). According to the survey carried out by Reza & Sabau (2022), it has been shown that monocropping has a negative impact on soil depletion and contributed to a decrease in soil nutrient diversity.

Although this cropping system is commercially efficient and profitable, it provides an unbuffered niche for parasitic species, increasing the crop's vulnerability to opportunistic insects, plants, and microorganisms (Blary *et al*., 2021; Dolezal *et al*., 2019; Suarez *et al*., 2023). Because a single crop is more vulnerable to a particular pathogen or pest, it accelerates the spread of diseases and pest outbreaks (Biber-Freudenberger *et al*., 2016; Cui *et al*., 2023; Kaur *et al*., 2021), increasing farmers' intensive reliance on pesticides and fertilizers, which affects water quality, human health, and wildlife population (Rahman, 2023). Increased use of chemical fertilizers and synthetic pesticides will ultimately increase emissions of greenhouse gases such as N2O (Reza & Sabau, 2022).

Compared to monocultures, intercropping contains more water, biomass, root system, and litter and can supply habitat for more organisms and contribute to flood mitigation, soil conservation, habitat quality, and carbon storage (Li *et al*., 2020; Ma *et al*., 2022; Sun *et al*., 2021). Climate change will increase the likelihood and severity of droughts into the future in many worldwide locations (Abdelmajid *et al*., 2021; Altieri *et al*., 2015; Chien *et al*., 2023; Leal Filho *et al*., 2023; Moldavan *et al*., 2023; Mutengwa *et al*., 2023; Shukla *et al*., 2019).

Natarajan & Willey (1986) studied the effect of drought on improved yields with multicropping by manipulating water stress on intercrops of sorghum and peanut, millet and peanut, and sorghum and millet. All the intercrops overyielded consistently at five levels of moisture availability, ranging from 297 to 584 mm of water applied over the growing season. Finn *et al*. (2018) found that grassland monocrop with experimental drought, decreased strongly the yield by 66%, in contrast, mixtures increased yield by 33% compared to the average of monocultures. Altieri *et al*. (2015) attested that multicropping has been shown to have higher yield stability and less productivity loss during drought than monocropping. The effects of drought on yield depend on environmental conditions, including agricultural intensity (Sun *et al*., 2021; Vogel *et al*., 2012; Zwicke *et al*., 2013), as well as pre-drought conditions and soil type, in particular, soil moisture retention properties (Hofer *et al*., 2016). Extreme weather events last longer, droughts become longer, moisture deficits during plant development during vegetation increase, soil moisture declines, and new pests and plant diseases appear (Cui *et al*., 2023; Moldavan *et al*., 2023) that agroecological farms are better able to counteract through the use of genetically diverse varieties of cultivated plants (Chien *et al*., 2023; Cui *et al*., 2023; Ma *et al*., 2022; Moldavan *et al*., 2023). Pathogen development and survival are most likely to be impacted by projected climate changes (Elad & Pertot, 2014). It is projected that a crop will become more vulnerable to numerous pests, diseases, and weeds as a result of changes in an area's climate

or weather pattern. While yields are predicted to decline at lower latitudes, they are forecast to increase in countries with high and middle latitudes (Rosenzweig *et al*., 2001). However, estimates indicate that a one-degree increase in temperature will result in a 10–25% increase in losses from insect pest infestation (Deutsch *et al*., 2018; Shrestha, 2019).

Nowhere are the consequences of biodiversity reduction more evident than in the realm of agricultural pest management. The instability of agroecosystems, which is manifested as the worsening of most insect pest problems, is increasingly linked to the expansion of crop monocultures at the expense of the natural vegetation, thereby decreasing local habitat diversity (Altieri and Letourneau, 1982). Plant communities that are modified to meet the special needs of humans become subject to heavy pest damage and generally the more intensely such communities are modified, the more abundant and serious the pests. The inherent self-regulation characteristics of natural communities are lost when humans modify such communities through the shattering of the fragile thread of community interactions. Agroecologists maintain that this breakdown can be repaired by restoring the shattered elements of community homeostasis through the addition or enhancement of biodiversity (Altieri, 1994).

For years, ecologists have debated the assumption that increased diversity fosters stability. Critical theoretical reviews on this subject are abundant in the literature, as well as reviews that use agricultural examples to bolster the theory (Andow, 1991). Most studies conclude that by mixing certain plant species with the primary host of a specialized herbivore gives a fairly consistent result: specialized species usually exhibit higher abundance in monocultures than in polycultures. In a recent review, Andow (1991) identified 209 published studies that deal with the effects of vegetation diversity in agroecosystems on herbivorus arthropod species. Fifty-two percent of the 287 total herbivore species examined in these studies were found to be less abundant in diversified systems than in monocultures, while only 15.3% (44 species) exhibited higher densities in polycultures.

Monoculture relies heavily on the use of chemical fertilizers and pesticides. The intensive use of chemical fertilizers can also affect soil properties and those of microbial communities and their functions (Pahalvi *et al*., 2021; van der Bom *et al*., 2018). Excessive use of nitrogen fertilizers can leach nitrates into water bodies, causing eutrophication and affecting aquatic life and drinking water quality (Khan *et al*., 2018). Phosphate is adsorbed on soil particles and transported to water bodies by soil erosion. Long-term excessive fertilizer use causes soil acidification, with long-term effects on soil productivity and soil protection (Mandal *et al*., 2020). In recent decades, the use of fertilizers and pesticides has increased the exposure of farmers, farm workers and the general population to these chemicals (Gupta, 2008). Dhankhar & Kumar (2023) attested that when fertilizers are applied to croplands, they are either directly or indirectly distributed into grains and vegetables, harming human health and lowering the nutrient density of the dominant plants. For instance, the nitrates and nitrites in fertilizers have been linked to cancer, birth defects, and other health issues like intoxications (Guo *et al*., 2020; Savci, 2012).

Furthermore, lead and cadmium-based fertilizers can be hazardous to both humans and animals, resulting in health difficulties such organ damage, neurological abnormalities, and developmental problems (Dhankhar & Kumar, (2023). Furthermore, Sharma (2017) reported that according to the U.S Environmental Protection Agency EPA's Office of Pesticide Programs, most of the pesticides contain ingredients that are cancerogenic to humans. The continued use of fertilizers hardens the soil, and can even modify its pH by increasing its acidification. For example, Pan *et al*. (2021) found that P addition slowed the process of nitrification in urea-treated soils, where a high N:P ratio appeared to be a major barrier. Ammonia-oxidizing bacteria's (AOB) response, which was more responsive to P addition than ammonia-oxidizing archaea's (AOA's) response, further corroborated this. The findings of this study indicated that the nitrification process in soil amended with urea was slowed by the application of P fertilizer, indicating that a synergistic feature of N and P nutrient management should be further investigated to slow N losses from agricultural systems.

Furthermore, the most frequently form of nitrogen or sulfur fertilizer in soil is nitrates or sulfate (S) (Brito *et al*., 2007; Vandenberghe *et al*., 2012), which is likely to exacerbate secondary salinization in the soil layer (Lu *et al*., 2019; Shen *et al*., 2016). Increased secondary salinization may lead to a reduction in soil fertilizer availability, which would reduce the productivity of crops, like cotton (Osanai *et al*., 2017; Tian *et al*., 2018), sunflower (Aziz *et al*., 2019), and maize (Lu *et al*., 2019; Rajeshwar & Khan, 2010). These will contribute to a drop in the content of organic matter in the soil, humus and the useful microbial load, relating to the decrease in quality of agricultural land, stunted plant growth, which is responsible for greenhouse gas emissions (Pahalvi *et al*., 2021). On the other hand, the excessive and long-term application of the chemical inputs is confirmed to contaminate the soil by heavy metals, including arsenic, mercury, and cadmium which are present either in the raw materials of the fertilizers (Atafar *et al*., 2010; Pogrzeba *et al*., 2018). Some heavy metals are required for plant development, such as, Fe, Cu, Mn, Mo and Zn, although they can be toxic to plants when present in excess. In addition, there are other Heavy Metals (Cd, Hg, Pb) that are irrelevant to plant development and can damage plants (Pogrzeba *et al*., 2018). The infiltration of these constituents, during the production processes, cannot be fully absorbed by the crops, and penetrates into the groundwater which causes their contamination (Chen *et al*., 2021). Nitrogen (N), phosphorus (P) and potassium (K) are the main macronutrients frequently required by crops to maximize their productivity (Gautam *et al*., 2020; Maathuis, 2009). Global nitrogen use, which is the single most important determinant of crop yield, is expected to increase by 1.6% per year until 2018, while phosphate use is expected to increase by

2.2% and potash 2.6%. In comparison, supplies of these three essentials are expected to grow by 3.7%, 2.7% and 4.2% per year, respectively (Nations, 2015).

The intensive use of nitrogen fertilizers causes emissions of ammonia and nitrogen oxide into the atmosphere and therefore has the effect of harming the ozone layer, its overuse can lead to an accumulation of nitrates in soils, leading to their acidification and salinization (Chen *et al*., 2021). In addition, the phenomenon of acidification accelerates the leaching process of calcium and magnesium, this can contribute to the reduction of the saturation of soils in nutrients and possibly their fertility (Chen *et al*., 2021; Pahalvi *et al*., 2021). These are suggested to influence the biodiversity and sustainability of soil. Consequently, it has become essential to protect and maintain soil productivity in the long term without resorting to destructive and unbalanced practices, in particular the irrational application of chemical inputs which leads to a degradation of soil quality and water (Abebe *et al*., 2022; Gautam *et al*., 2020; NING *et al*., 2017; Wu *et al*., 2021).

The Green Revolution may not be the only reason for biodiversity decline. But it's definitely a major factor. According to the FAO's State of the World's Biodiversity for Food and Agriculture (2019), while more than 6 000 plant species have been cultivated for food, fewer than 200 make substantial contributions to global food output, with only nine accounting for 66 percent of total crop production in 2014. Although it is not possible to make definitive statements about global trends in the erosion of on-farm crop diversity, evidence suggests that, overall, the diversity present in farmers' fields has declined and that threats to diversity are getting stronger (FAO, 2019). Biodiversity serves as a foundational component of natural ecosystems and the global food system. Its ongoing decline poses significant risks to ecological stability and the continuity of life-supporting processes. Without urgent and effective intervention to halt and reverse this trend, the trajectory points toward an uncertain and potentially destabilizing future for human societies and the planet at large.

3.0 Regenerative Agriculture: Principles and Practices

The Green Revolution in the 1950s and 1960s led to a significant increase in productivity through modern machinery, artificial fertilisers and highly bred crop varieties (Evenson & Gollin, 2003). At the same time, the impact on the environment, including on soils, water quality and biodiversity, has often been neglected. As the world's population and the demand for agricultural products is growing further, the environmental impacts are not only becoming more acute, but also have long-term implications for food security itself. Global food systems will remain highly dependent on ecosystem services and abiotic factors, some of which are also changing for the worse, most notably climate (Foley *et al*., 2005; Wheeler & von Braun, 2013).

To overcome the negative consequences of conventional farming, alternative approaches have arisen in recent decades. These are often subsumed under the term sustainable agriculture, defined by the Food and Agriculture Organization (FAO) as " ... the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development ... conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable" (FAO, 1989).

Various approaches have been developed and implemented to achieve this transformation (Oberč & Arroyo Schnell, 2020). One established approach is conservation agriculture (CA), which has its roots in conservation tillage as a solution that emerged from the "Dust Bowl" that affected US and Canadian prairies in the 1930s (Hobbs, 2007). In the 1970s and 1980s, this approach was complemented by the practice of intercropping and crop rotations and has been employed widely under the label CA since the 1990s. The FAO highlights three key principles of CA: minimisation of soil disturbances, enhancement or maintenance of a protective organic cover, cultivation of a wide range of plant species (FAO, 2011).

Conservation agriculture is the basis of regenerative agriculture. The concept of a regenerative agriculture can be traced back to the cusp of the 1980s discussions of sustainability (Gabel, 1979; Sampson, 1982; Rodale, 1983). Regenerative agriculture adopts the principles of conservation agriculture that's meant to maintain soil health. Where regenerative agriculture diverges is its broader focus on increasing biodiversity in general and creating a closed nutrient cycle in combination with livestock management at farm level. It includes additional approaches such as manure composting, rotational grazing and silvopasture in grassland management (Smith *et al*., 2021).

In practice, regenerative agriculture and conservation agriculture involve similar cropping systems and the terms are often used interchangeably. Some scholars and practitioners additionally ascribe a social dimension to RA (Müller, 2020). Some of the more holistic regenerative approaches transcend soil regeneration and additionally aim at "regenerating" the social aspects related to agriculture. For example, in terms of good livelihoods, social relationships and stable incomes (LaCanne & Lundgren, 2018), future perspectives, and (re) building human–nature relationships (Gordon *et al*., 2022; Hes & Rose, 2019).

Newton *et al*. (2020), in their comprehensive meta-analysis, are the only researchers to date who have explicitly categorized regenerative agricultural practices based on a thorough review of the literature. Drawing from 229 peer-reviewed journal articles, they identified the five most frequently cited practices. These include: using no or low external inputs while maximizing on-farm inputs (26.4%), integrating livestock into farming systems (19.0%),

avoiding synthetic pesticides (12.4%), avoiding synthetic fertilizers (12.4%), and reducing tillage (11.6%). This list reflects the academic emphasis on minimizing synthetic inputs and enhancing self-sufficiency within farm ecosystems. In contrast, when examining 25 practitioner websites, Newton *et al.* found a slightly different prioritization of regenerative practices. The most commonly mentioned were reducing tillage and integrating livestock, both cited by 40.9% of sources. These were followed by the use of cover crops (36.4%), crop rotations (31.8%), and minimizing external inputs in favor of on-farm resources (31.8%). This practitioner-focused perspective highlights a more operational and practical orientation toward soil health and system resilience, indicating both overlap and divergence between academic and on-the-ground understandings of regenerative agriculture.

Conclusively, regenerative practices contribute significantly to biodiversity by creating diverse, resilient agroecosystems that support a wide range of organisms. Reducing or eliminating synthetic inputs like pesticides and fertilizers helps preserve beneficial insects, soil microbes, and pollinators, which are often harmed by chemical exposure. Integrating livestock and using cover crops and crop rotations introduce a variety of plant and animal species into the farming system, breaking pest and disease cycles and enriching habitat complexity. Additionally, reducing tillage protects soil structure and fosters underground biodiversity, including fungi, earthworms, and microbial communities. Altogether, these practices enhance both above- and below-ground biodiversity, promoting ecosystem balance and long-term sustainability.

4.0 Evidence of Biodiversity Recovery in Regenerative Agriculture

Biodiversity loss is a critical global concern, driven largely by conventional agricultural practices that simplify ecosystems and rely heavily on synthetic inputs. In response, regenerative farming has emerged as a holistic approach aimed at restoring ecological balance through methods that enhance soil health, reduce chemical dependence, and increase biodiversity. A growing body of research suggests that regenerative practices—such as cover cropping, crop rotation, livestock integration, and minimal tillage—not only sustain productivity but also foster the recovery of biodiversity at multiple trophic levels. Regenerative agriculture restores soil biodiversity by reversing the degradative effects of monoculture, which typically depletes soil life through uniform cropping, heavy tillage, and chemical input use. It promotes a heterogeneous and nutrient-rich soil environment that supports diverse microbial communities, fungi, earthworms, and other soil organisms.

Microorganisms, for example, are crucial to soil biodiversity and ecosystem functioning. They decompose organic matter, releasing nutrients essential for plant growth. Bacteria and fungi work in tandem to break down complex organic materials, converting them into forms that plants can readily absorb. For instance, mycorrhizal fungi form symbiotic relationships with plant roots, facilitating the uptake of water and nutrients, especially phosphorus, which is crucial for plant health (Smith & Read, 2008). Fungi, particularly mycorrhizal species, are essential for maintaining soil biodiversity. They create extensive networks that connect plant roots, allowing for nutrient exchange not only between plants but also with soil microorganisms. This network improves the overallhealth of the soil ecosystem, enhances plant resilience, and facilitates the transfer of water and nutrients over long distances (van der Heijden *et al*.,2008). In summary, regenerative systems foster the recovery and proliferation of soil biodiversity that monoculture systems often diminish or destroy.

Plant diversity is a cornerstone of agroecosystem resilience. Increasing cropping diversity in field has been shown to lead to increased crop and forage yield in some contexts (Smith *et al*., 2008). This is achieved through the establishment of diverse plant species that have complementary nutrient requirements and support beneficial interactions (Beillouin *et al*., 2021). Crop diversity can also improve yield stability by reducing the risks associated with monocultures and susceptibility to pests, diseases and climate shocks (Raseduzzaman and Jensen, 2017).

Furthermore, increased on-farm biodiversity can provide a greater range of habitats to support pollinators, crucial for the success of some crops and fruit trees (Nicholls and Altieri, 2013; Pywell *et al*., 2015). Increased biodiversity promotes natural pest suppression, as a diverse range of predators and beneficial organisms helps regulate pest populations (Gurr *et al*., 2003; He *et al*., 2019; Nicholls and Altieri, 2013). Increased crop diversity or the use of cover crops can also suppress weed pressure, as diverse plant communities compete with and inhibit weed growth (Isbell *et al*., 2017). Increased diversity in grassland has been shown to be associated with higher levels of soil carbon and nitrogen, and invertebrate abundance in soils (Norton *et al*., 2022). On-farm diversification of crops is known to enhance biodiversity and a range of ecosystem services such as supporting pollinators, pest control, nutrient cycling, soil fertility and water regulation, without compromising crop yields (Brooker *et al*., 2015; Tamburini *et al*., 2020).

The results of a meta-analysis of 53 individual European studies on the effects of agroforestry on ecosystem services showed a strong positive effect of agroforestry on biodiversity, with the effect size varying depending on the taxa and systems studied; the strongest positive effects were seen for birds and silvo-arable systems (Torralba *et al*., 2016).

RizomaAgro is developing regenerative agriculture in three farms in Brazil, which have a size of over 2,000 hectares. In 2022, it reported a significant improvement in environmental indicators related to carbon

sequestration, biodiversity and water retention. According to the report, it tripled the number of species of pollinators and natural enemies of pests (RizomaAgro, 2022).

Regenerative agriculture can reduce on-farm herbicide and pesticide use. Besides supporting pollinators, cover and companion crops support a broad spectrum of beneficial insects through creation of habitats during the growth and senescence phases of the crop. Furthermore, companion crops can be used to divert insect pests away from the main cash crop and could also act as barriers against fungal pathogen spread throughout the cash crop (Huss *et al*., 2022). There is potential to reduce herbicide and pesticide use if weeds, pests and diseases are successfully suppressed through companion cropping (Osipitan *et al*., 2019). Potential benefits from mixed crops include the maintenance of crop yields with reduced inputs, such as herbicides and pesticides and greater resilience to environmental variability such as summer droughts (Weih *et al*., 2022). By reducing the reliance on chemical pesticides and fostering a diverse insect community, regenerative agriculture creates a more resilient system capable of self-regulation (Benton *et al*., 2003). Studies have shown that farms with higher plant diversity can significantly boost pollinator visitation rates, leading to improved crop yields and ecosystem health (Klein *et al*., 2007).

In conclusion, the evidence presented underscores that regenerative agriculture offers a viable and ecologically sound alternative to conventional practices, with significant benefits for soil health, biodiversity restoration, ecosystem services, and long-term farm productivity, ultimately contributing to a more resilient and sustainable agricultural system.

5.0 Conclusion

The health of an ecosystem is measured by the degree of its diversity. This paper has demonstrated that regenerative agriculture offers a powerful framework for reversing biodiversity loss driven by conventional farming practices. Through practices such as cover cropping, crop rotation, livestock integration, and minimal tillage, regenerative systems foster rich and resilient ecosystems both above and below ground. The restoration of soil microbial communities, enhancement of plant diversity, support for pollinators, and natural pest regulation all contribute to healthier, more self-sustaining agroecosystems.

Despite these promising outcomes, the widespread adoption of regenerative practices faces several challenges—including economic and policy barriers, limited farmer training, and insufficient market incentives. There may also be trade-offs, particularly between yield stability and biodiversity gains, that require context-specific evaluation and management.

To fully realize the potential of regenerative agriculture, long-term biodiversity monitoring must be prioritized, alongside efforts to integrate these practices into national and international agricultural policies. Scaling biodiversity-friendly farming will require coordinated research, cross-sectoral collaboration, and financial frameworks that reward ecological stewardship.

In conclusion, regenerative agriculture stands out as a viable pathway to restore biodiversity while sustaining agricultural productivity. This calls for deeper interdisciplinary research and robust policy support to overcome barriers and ensure its benefits are accessible, scalable, and lasting as the world moves toward sustainability.

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Comparison of Secondary Models for Modeling the Growth of *Salmonella* in Leafy Greens

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Abstract

An estimated 550 million individuals worldwide suffer from food-related illnesses, which also cost the economy billions of dollars annually and result in 230,000 fatalities. If it were possible to identify and track the growth or survival of pathogen microorganisms, these illnesses and expenses might be decreased. However, monitoring the development or survival of bacteria using traditional microbiological methods is very expensive and labor-intensive, and the knowledge gained is not cumulative. Instead of employing conventional microbiological techniques, predictive microbiology has been created to forecast microbial behavior during food processing using precise and adaptable mathematical models. Primary, secondary, and tertiary models are the three general categories into which mathematical models fall. Secondary models examine how parameters that appear in primary modeling approaches change in response to one or more environmental factors, such as pH, temperature, etc. In order to ascertain which secondary models were most suitable for Salmonella in leafy greens, this study compared the suboptimal Ratkowsky square-root, suboptimal Huang square-root, Cardinal, and Arrhenius-type models. The best model to fit data on the maximum growth rate as a function of temperature, according to the findings of the current study, was the Arrhenius-type model. These findings shed light on predictive microbiology and aid researchers and food microbiologists in selecting the best secondary growth prediction model.

Key Words: *Food safety, Foodborne outbreaks, pathogens, Predictive microbiology, lettuce*

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Effect Of Pre- Sowing Seed Treatment Of Moringa *(Moringa oleifera*) On Sandy Loam Soil

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Abstract

Sowing seed treatments have been reported to have influence on the germination percentage and growth performance, which could affect crop yield when transplanted to the field. Replacing chemically expensive and laborious pre-treatment with physically pre-treatment with physically pre-treated seed reduce the cost of producing moringa by resource poor farmers. Therefore a Nursery experiment was conducted at the Department of Agronomy, Bayero University Kano, to examined effect of three pre sowing seed treatment, dry seed with complete coat (DSCC), dry cracked seed with complete coat (DCSC), soaked seed with complete coat (SSCC,) soaked cracked seed coat, (SCSC), on the germination percentage and growth indicator of *moringa* plants. The treatment was replicated three time in a completely randomized design, the result indicated that DCSC had significantly higher (P=0.05) seed germination percentage; than SCSC and SSCC however the highest seed germination percentage was observed under DSCC. By 55.5%, 44.4%, 33.3%, and 88.9% respectively at 1 week after sowing (WAS). The experiment provides information about sowing seed treatment of *moringa oleifera* which could replace the chemically expensive and laborious sowing seed treatment technique for optimal *moringa* production. in term of germination. Percentage sowing seed treatment have no significant effect on *moringa* seed germination percentage, this indicate that the resource- poor farmers there is no need to treat *moringa* seed before sowing into sandy loam soil.

Introduction

Moringa oleifera is among the world's most useful plants. its grown throughout the tropics for human food, like stock forage, medicine, dye and water purification. It is known by names in different countries, but is popularly called the "drumstick tree" for its pod that are used by drummer and the "horse radish tree" for the floor of its roots, it is also one of the world's most nutritious crops. The leave of *Moringa* have more beta carotene than carrots, more protein than peas, more vitamin C than orange, more calcium than Milk, more potassium than banana, and more iron than spinach. Native to south Asia, it is a vital source of nutrition in this region, where most of the poor people live. The multiple uses of *Moringa* have attracted the attention of the researchers, development workers, and farmers, (Igbal et. al, 2006). *Moringa*oleifera belong to the monogenetic family of shrub and trees, Moringaceae. *Moringaoleifera*is cultivated throughout the Middle East and in most of the tropic belt. It was introduce in eastern Africa from India at beginning of the 20th century. *Moringaoleifera* is a medium – sized tree that reaches about 10m in height. It has straight traced about 10 – 30cm thick with bark that is whitish grey, carry with longitudinal cracks. It also has a tuberous tap root to tolerate hash conditions. The umbrella shaped tree comes with a loose crown of feathery foliage. The foliage is over green or decisions depending on the environment. Scented flowers arranged in drooping panicles. Flower are insect pollinated and required a large number of insect visitations, with bees the most common (Fuglie, 2001) Globally, agriculture play a key role on improving livelihood especially in rural communities. Crop production is the main stay of agriculture commodity. It provide up to 50% of the value of agricultural output globally and one third in developing countries (Delgado et. al, 1999). During the past 3 decades, rapid increase and development in the crop production sector has led to "Crop revolution" or "food revolution" due to rapid technology invasion in this sector, and especially crop improvement of crop industry. This increase in crop production has emerged to be more impressive – than animals production (Sanoncy, 1995) to meet the demand for nutritionally balanced food for the worlds increase population and relieve the intense pressure on land used and natural resources, plants spices used as food must be diversified, inclusion of a wide array of indigenous vegetable species in cereal, tubers and livestock – based agriculture will be crucial to contribute to food and nutritional security and diversification for stake holder in the subsistence farming system that predominate in the under developed and developing world, therefore, improving the genetic potential of vegetable like (*MoringaSpp*) is of paramount importance it has considerable area under cultivation in Africa and India with huge socio-economic potential. *Moringa*is called Zogale in Hausa, English *Moringa* tree, ben oil tree, cabbage tree, clarifier tree, horse raddish tree west India ben in Ibgo (OkweOyrbo), Yoruba (Ew)The ultimate importance of nursery establishment is to produce *Moringa* seedling that when planted and managed will improve the living condition of the people in affected area through the provision of basic certain requirement and by

reserving the environment degradation, (Hajji, 2011).Nursery establishment as new technology introduce for former adaptation and subsequent seeding production in improving germination rate particularly in extreme northern Nigeria, however it is said to rate that people's knowledge about seed and their socio- economic benefic have found inadequate, the ultimate important of nursery establishment is to produce seedling that when planted and managed will improve the living condition of the people in affected areas .

Pre sowing seed treatment is the influence on germinate percentage and growth performance which could affect the crop yield when transplanted to the field ,Is the replacing the chemically expenses and laborious pre –treatment with physically pre-treated seed could reduce the cost of reducing *moringa* by resource poor farmers.

Seed treatment method : some of these crop are propagated by seed while some are vegetatively propagated most of these forage crop are perennials, that is why most of the paddocks generate every rainy season and most of the paddocks are maintained for over 70 days Back. The purpose of seed treatment is to break seed dormancy so as to improve seed germination and emergence, some method are hot water method, mechanical method, acid/chemical method, rhizobium inoculation. The seed are said to be dormant if it does not germinate after 15 days.Sandy loam is a types of soil used for gardening. The types of soil are made up of sand along with varying around of soil and clay sand soil are used for gardening because the soil organic matters and moderating water retention.

Given high nutritive value of *Moringa* and its implication as important human food supplement, it become imperative that studies into the most ideal condition for its initial establishment in the nursery are carried out, such study will ensure high established rates of the seeds sown out, as the seed has also proven to be very difficult to acquire, high initial seedling establishment result in increased production levels, thus availing more *moringa* produce to those in need of it as a food source and also identify the most ideal seed priming method for optimum germination and initial seedling establishment and growth because seed priming increase germination percentage and initial seedling establishment.

Moringa is one of the vegetable plant with high nutritive value and it is produced in small quantity by local farmers in Nigeria therefore there is need to encourage the farmer to used specific seed treatment which help in faster germination rate and grow and harvest earlier.

Methodology

Experimental Site

The experiment was conducted in the nursery site, Department of Agronomy faculty of Agriculture, Bayero University, Kano, located within latitude $13^0$53' N – 10^0 25' N and longitude 7^0 40'E – 10^0 53' E situated in Sudan savannah ecological zone of Nigeria (Olofin, 2007). The zone characterized by distinct dry and wet season the rainy season started in May/June and end in September/October. The dry season start from November to April with occurrence of hamattan in November to January. The ambient temperaturerange from 16.7^{0}C – 22 8^{0}C in the month of January to June and 23.9^{0}C to 26.7^{0}C in July to December (Anon, 2010) an Average month rainfall of 0 to 300mm recorded in January to June and 780mm to 1320mm in July to December (KNARDA, 2001). The relative humidity range between 40 to 50% (Olofin, 2007).

Experimental Design

The experiment was laid out in completely randomize design(CRD), the pre-sowing seed treatment are as fallowed (i) dry seed with complete coat (DSCC) (ii) dry cracked seed coat (DSC) seed coat was cracked using pliers before sowing (iii) soaked seed with complete coat (SSCC) – seed was soaked with water in a container for 24 hours prior to sowing. The seed sowing was done in poly-bag, (V) soaked cracked seed coat (SCC) seed were cracked using plier and soaked with water for 24 hours before sown. 2kg soil capacity, the treatment was replicated three times in a nursery. The sowing was done with the aid of a calibrated stick to ensure uniform sowing depth of 2cm for all treatment (Oshunsanya, et,al 2017).

Data Collection:

The data was collected for the following parameters:

Germination percentage, **Plant height** (cm); the height of the plant will be measured weekly from the ground level to the tip of terminated bud, with the aid of meter rule, and this will be carried out for 1,2,3,4,and 8 (WAS). **Stem girth**: the stem girth was measured by tighten a thread round the Circumstance of the plants; meter rule was used to determine the length of the measured Circumstances from the thread. **Number of leaf**: the total number of the leaves was obtained by direct counting of the leaves.

Data Analysis

The data collected was subjected to analysis of variance using Genstat (2018) software version 11. The means were separated using Students Newman Keul Test (SNK).

Results and Discussion

Table 1. Effect of Pre-Sowing seed treatment on plant height (cm) of *Moringa oleifera*

	WEEKS AFTER SOWING							
Treatment	1	2	3	4	5	6	7	8
DSCC	14.00	28.50	34.80	42.50	45.40	49.10	59.40	53.00
DCSC	13.13	20.40	33.70	39.40	44.20	59.40	49.13	52.40
SSCC	8.83	20.70	29.60	30.60	43.30	48.50	48.47	50.70
SCSC	2.17	15.70	21.90	31.90	43.30	44.00	44.00	47.30
SED	1.69	5.72	3.91	5.39	4.29	7.41	8.06	5.28

SED= standard error differences. Means with the same letters are not significantly at 5% level of probability using Student Newmans Keul. DSCC: Dry seed with complete coat, DCSC: Dry cracked seed with complete coat, SSCC: Soaked seed with complete coat, SCSC: Soaked cracked seed with complete coat

Table 2. Stem diameter (MM) of *Moringa oleifera* at BUK

	WEEKS AFTER SOWING							
Treatment	1	2	3	4	5	6	7	8
DSCC	1.13	1.03	1.27	1.33	1.77	2.43	2.53	2.73
DCSC	1.30	1.00	1.17	1.53	1.83	2.50	2.50	2.77
SSCC	1.17	1.00	1.17	1.367	1.90	2.00	2.17	2.30
SCSC	0.90	1.00	0.17	1.37	1.90	2.00	2.17	2.30
SED	0.22	0.21	0.14	0.14	0.23	0.98	0.31	0.23

SED= standard error differences. Means with the same letters are not significantly at 5% level of probability using Student Newmans Keul. DSCC: Dry seed with complete coat, DCSC: Dry cracked seed with complete coat, SSCC: Soaked seed with complete coat, SCSC: Soaked cracked seed with complete coat

Table 3. Number of leaves of *Moringa oleifera*

	WEEKS AFTER SOWING							
Treatment	1	2	3	4	5	6	7	8
DSCC	11.33	24.33	50.33	50.33	97.30	139.70a	122.30a	147.00
DCSC	11.00	25.33	51.00	51.00	115.7	122.30ab	139.70ab	131.00
SSCC	6.00	17.67	21.00	21.00	104.30	67.30c	67.30c	104.70
SCSC	10.00	22.67	42.67	42.67	91.70	97.00bc	97.00bc	75.70
SED	1.72	4.61	11.11	8.90	23.33	13.21	13.21	13.50

SED= standard error differences. Means with the same letters are not significantly at 5% level of probability using Student Newmans Keul. DSCC: Dry seed with complete coat, DCSC: Dry cracked seed with complete coat, SSCC: Soaked seed with complete coat, SCSC: Soaked cracked seed with complete coat.

Discussions

Germination percentage at first WAS

The seed germination percentage as affected by the various pre- sowing seed treatment as presented above, the germination percentage per treatment was significantly ($p<0.05$) higher under DCSC (55.5%) then SCSC (44.4%) and SSCC (33.3%) however the highest seed germination percentage (88.9%) was observed under DSCC. This was in lined with finding of (Oshunsanya, 2015) who observed that the *moringa* seed without sowing treatment(DSCC) fastened the seed germination, this confirm that, in spite of the treatment, achieved high germination percentage. This result supports the claim that considers pre germination seed treatment unnecessary.

Effect of pre sowing seed treatment on plant height (cm) of *Moringa oleifera*

The result as presented in (Table 1) shows that there is no significant difference ($p>0.05$) in term of plant height between the treatments in all the weeks. This finding indicates that sowing seed treatment do not have effect in plant height. Although, some scientific results show that soaking is an option for improving the Moringa seed germination, other reports consider it unnecessary (Padilla, C., Fraga, N. and Suarez, M. 2012).

Effect of pre sowing seed treatments on stem diameter (mm) of *Moringaoleifera*

The result as presented in (Table 2) showed that there is no significant differences ($p>0.05$) in term of stem diameter between the treatment in all the weeks, this indicate that sowing treatment do not have effect on stem diameter. The non significance differences were attributed to the genetic constituent of the variety and

environmental condition. This finding indicate pre sowing treatment have no influence in stem diameter of the *moringa* plant Sogbo, (2006).

Effect of pre sowing seed treatment on leave number of *Moringa olifeira*

The significant differences was observed only in week 6 and 7 as presented in (Table 3.) in which at week 6 DSCC has the highest means value followed by DCSC then SSCC. The least mean value was observed in SCSC. But there were no statistical differences between DSCC and DCSC. At week 7 they have shown the same effect. This difference was attributed to managements such as pest attacked and may be attributed to the genetic makeup of the variety. This are in line with the finding of Raja (2013). That pre sowing treatment have influence in determining growth parameters (leaves numbers).

Conclusion

The experiment provides information about pre-sowing seed treatment of *moringa oleifera* which could replace the chemically expensive and laborious pre-sowing seed treatment technique for optimal *moringa* production in term of germination. Percentage pre-sowing seed treatment have no significant effect on *moringa* seed germination percentage, this indicate that the resource- poor farmers there is no need to treat *moringa* seed before sowing into sandy loan soil.

Recommendation

From the studies carried out, dry seed with complete coat which is control (DSCC) have proven to have significant effects on germination percentage of the *moringa* plants. Therefore in addition further research should be conducted to examine more about pre-sowing seed treatment

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Utilisation of Bovine Rumen Filtrate for Biodegradation of Sweet Orange Peel (*Citrus sinensis*) and Effect on Rabbit Performance

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Abstract

A feeding trial was conducted with four to six-week old rabbits (n=30) to determine their growth and nutrient digestibility on diets in order to evaluate the maize replacement value of sweet orange peel biodegraded with rumen filtrate. Rumen filtrate was obtained from the rumen content and liquor of four randomly selected slaughtered cattle, to which water was added in ratio 1:1, and filtrate manually squeezed out. Freshly collected sweet orange peel was divided to five batches of 5 kg each. Rumen filtrate was added to and mixed with one of 5 kg each in ratio 1:5, 2:5, 3:5, 4:5 and 5:5 and biodegraded for 24 hrs, sundried and milled. Each of replaced 50% maize in the control diet (T1) of rabbits to obtain diets T2, T3, T4, T5 and T6, respectively. Thirty mixed breed exotic rabbit of both sexes were randomly allocated to six diets of five rabbits each. Rabbits were fed ad libitum and provided adequate drinking water in a 77-day feeding trial. Growth indices and coefficient of digestibility of nutrients were determined. Experimental diets had no significant effect ($p>0.05$) on final live body weight, feed intake, body weight gain, feed conversion and protein intake, but protein efficiency ratio differed significantly ($p<0.05$) with higher value of 2.10 in T5. Diets had varied significant effect ($p<0.05$) on the coefficients of digestibility of nutrients and improved crude protein digestibility. Bovine rumen filtrate can be used to treat sweet orange peel in a ratio of 4 litre rumen filtrate : 5kg for its biodegradation to improve its feed value, and as a replacement for dietary maize at 50% level in growing rabbit diet.

Keywords: *Rumen filtrate, biodegradation, peel, rabbit*

Introduction

Food is a necessity in human life as it helps in body growth and sustenance of diverse life activities. However, the world is facing food insecurity which is a threat to human survival most especially in the developing countries. The shortage in animal food production with increase in population growth brings about the current food crisis in many developing countries. In Nigeria, over 70% of the citizens are involved in agriculture and mainly at subsistence level (Babamaaji and Ekwe, 2023). In spite of its contribution to the nation's economy, the sector confronts a myriad of problems which affect productivity, prominent among which are climate change, land degradation which reduces cultivable land mass, inadequate local production of feed ingredients, post-harvest losses and high production cost. These have adverse effect on agricultural productivity, causing increased food importation due to population increase and decreased food sufficiency. Nigeria's population is estimated at 223.8 million with a growth rate of 2.41% (Worldometer, 2024), and dietary protein deficiency is a major problem partly, because the demand for protein of animal origin is greater than supply. The recent average animal protein intake in Nigeria put at 6 – 8 g/day (Have et al., 2020) is dismal. The global average daily total protein intake based on a reference intake value of 0.83 g/kg of body weight is 64 g, and in advanced economies more than 60% of protein intake comes from animal sources whereas, in Africa, India and other food deficient countries it ranges from 20 – 25% of total protein (Capper et al., 2013). Animal production in Nigeria remains underexploited, thus, a dire need for an appreciable step-up in livestock production to mitigate the critical shortage of animal protein using animals like the domestic rabbit which when compared with other livestock is characterized by early sexual maturity, high prolificacy, relatively short gestation period, short generation interval, high productive potential, rapid growth, in addition to its ability to utilize forages and fibrous plant materials and agricultural wastes. Rabbit is thus regarded as an animal at the nexus of food production and bioscience research for sustainable development in developing countries (Sikiru et al., 2020). Sweet orange peels are abundant citrus wastes in most part of Nigeria because of the heavy consumption of the fruit. It is high in metabolisable energy content, and similar to maize in crude protein (Jobo and Oluremi, 2023) and can be an alternative feed ingredient to maize in rabbit nutrition because of its relatively high crude fibre.

The study determined the feed value of sweet orange peels biodegraded with rumen filtrate from bovine species in grower rabbit performance

Materials And Methods

The feeding trial was carried out in the Rabbitary unit at the Teaching and Research Farm, Federal University of Agriculture, Makurdi, Nigeria located in latitude 60^0 - 80^0 N and Longitude 6^0 - 10^0 E. Makurdi has an annual precipitation ranging between 508 mm to 1016 mm, for a six to eight-month period, minimum temperature of 22.80 ^oC and maximum temperature of 40.03 ^oC and, relative humidity between 37.3% and 59.2% (Audu et al., 2022).

Fresh sweet orange peels (SOP) were collected from orange fruit retailers on the Campus and Wadata, in Makurdi metropolis and treated with rumen filtrate (RF). Fresh rumen content together with liquor was collected in covered plastics buckets from four randomly selected slaughtered cattle in a Government abattoir within the metropolis. The RF was analysed for its microbial content (Cheesbrough, 2005) in the University's Veterinary Microbiology Laboratory. Water was added to rumen content and liquor in the ratio of 1 L : 1 kg of rumen content, thoroughly stirred and squeezed manually to extract the rumen filtrate. The RF was then added to and mixed with SOP in the ratio of 1 L : 5 kg, 2 L : 5 kg, 3 L : 5 kg, 4 L : 5 kg and 5 L : 5 kg, to obtain biodegraded SOP 1,, SOP 2, SOP 3, SOP 4 and SOP 5,, respectively. Each mixture was poured in a feed sack, kept in a shade and allowed to ferment for 24 hours. Thereafter, biodegraded SOPs were spread thinly on a concrete floor and sundried until about 10% moisture content was attained within 24 – 48 hours. Samples of SOP 1,, SOP 2, SOP 3, SOP 4 and SOP 5 were milled and analysed for its proximate constituents (A.O.A.C., 2015) at the University's Animal Nutrition Laboratory and the metabolisable energy calculated (Pauzenga, 1985) as shown in Table 1.
Six experimental diets were formulated, using sweet orange peel (SOP) biodegraded with rumen filtrate (RF) in ratios 1 litre RF : 5 kg SOP (SOP 1), 2 litre RF : 5 kg SOP (SOP 2), 3 litre RF : 5 kg SOP (SOP 3), 4 litre RF : 5 kg SOP (SOP 4), and 5 litre RF : 5 kg SOP (SOP 5), as replacement for 50% maize in the control diet (T1), to obtain diets T2, T3, T4, T5 and T6, respectively (Table 2). The experimental animals were four to six-week old 30 mixed breed exotic rabbits of both sexes, housed in separate cages, and randomly assigned to the six diets at the rate of five rabbit per diet group. Each rabbit in a diet group served as a replicate, all rabbits were fed *ad-libitum* and drinking water supplied without restriction. The feeding trial lasted for 77 days. The experiment was a completely block randomized design. Medications given were antibiotics (Tridox) intramuscularly, coccidiostat (Amprolium) and Zantriviral were given orally using water as the administration route. Vitalyte was given as antistress.

Table 1: Proximate constituents of Biodegraded sweet orange peel (%DM)

Nutrients	SOP1	SOP2	SOP3	S0P4	SOP5
Dry matter	89.40	88.86	87.78	88.73	85.48
Crude protein (CP)	5.87	6.40	6.98	7.39	9.73
Crude fibre	9.97	10.03	10.48	11.75	12.20
Ether extract (EE)	1.84	2.23	2.10	2.30	2.11
Ash	9.32	10.38	10.21	10.10	10.40
Nitrogen free extract	73.00	70.42	70.23	68.45	65.56
ME[1] (kcal/kg)	2958.01	2917.56	2921.74	2890.29	2858.51

[1]ME = Metabolisable energy, SOP = sweet orange peel.

Table 2: Gross composition of experimental diets

Ingredients (%)	T1	T2	T3	T4	T5	T6
Maize	41.44	20.72	20.72	20.72	20.72	20.72
Sweet orange peel	0	20.72	20.72	20.72	20.72	20.72
Fixed ingredients[1]	58.56	58.56	58.56	58.56	58.56	58.56
Total	100	100	100	100	100	100

[1]Fixed ingredients (%); soybean 5.00, blood meal 0.50, rice bran 27.30, brewers dried grain 22.45, bone ash 2.81, vitamin/mineral premix 0.25, table salt 0.25.

The performance data collected were;

i. Initial body weight (IBW)
ii. Final body weight (FBW)
iii. Body weight gain (BWG) = $FBW - IBW \ / \ 96 \ days$
iv. Daily feed intake (DFI) = $\frac{Feed\ supplied - Unconsumed\ feed}{96\ days}$
v. Feed conversion ratio (FCR) = $\frac{DFI}{BWG}$
vi. Protein intake (PI) = DFI x % crude protein in feed
vii. Protein efficiency ratio (PER) = BWG / PI

At the end of the eleventh week of the feeding trial, three rabbits were selected per treatment having an average weight similar to treatments average weight, and used for nutrient digestibility evaluation. Experimental diets were withdrawn 18 hours prior to commencement of digestibility trial to allow for the elimination of the residual feed in the gut. Thereafter, 75% of their daily feed intake was supplied to each rabbit for four days and the corresponding faecal droppings collected and used to determine coefficient of digestibility of nutrients. Wet faecal collection was done daily using mosquito net tied under respective cages, weighed, oven dried at 105 ^{o}C for 24 hrs and weighed. The faecal droppings for each replicate was bulked and subjected to proximate analysis at the Nutrition Laboratory of the Department of Animal Nutrition in the Federal University of Agriculture Makurdi. Nutrient digestibility was computed as;
Nutrient digestibility = Nutrient consumed – Nutrient in faeces / Nutrient consumed x 100.

Data generated were subjected to the analysis of variance (ANOVA) using SPSS (2012), and the means of significantly ($P<0.05$) different indices separated with the least significant difference (LSD).

Results And Discussion

The microbial analysis of the rumen content showed that its homogenous mixture contained bacteria *E.coli* and *Klebseilla* spp. in the range of 2.4 x 10^6 – 2.8 x 10^6 cfu/g and *Aspergillus* spp. *a* fungal spp. in the range of 0.5 x 10^6 – 0.6 x 10^6 cfu/g. The ruminal ecosystem has a large diversity of microorganisms; bacteria, fungi and protozoa (Castillo-Gonzalez, 2014), working synergistically for the nutritional transformation of forage, the main feed of ruminant animals to produce metabolic energy for various physiological activities. The presence of these bacterial and fungal isolates in rumen filtrate shows that there are some ruminal microbes which can survive outside the ruminal ecosystem and can be useful to stimulate biodegradation process *in vitro* to improve the feed value of some crop residues and agricultural wastes such as sweet orange peels. The crude protein content of biodegraded sweet orange peel increased as the quantity of RF added to SOP increased from 1:5 to 5:5. The microbial load in the rumen filtrate was expected to increase the higher the quantity of rumen filtrate added to SOP. This can cause higher cell multiplication and more microbial cell mass thereby causing the increase in the crude protein content of SOP. The crude fibre level of the biodegraded SOP increased while, the nitrogen free extracts decreased as the ratio of the mixture of RF to SOP increased from 1:5 to 5:5, implying that crude fibre in the biodegraded SOP may contain higher indigestible fractions. The microbial isolates in the rumen filtrate *Klebseilla* spp., *E.coli* and *Aspergillus* spp. appeared unable to alter the structure of SOP by reducing its crude fibre content. Ash content increased as the RF : SOP ratio increased from 1:5 to 5:5, possibly because of the mineral content in the rumen mass due to mostly forage basal diet consumed by the cattle. The higher ether extract in the rumen filtrate treated SOP might be the consequence of the lipolytic activity of *E.coli*, one of the microbial isolates (Henne et al., 2020). There was a slight decrease in the metabolisable energy content of biodegraded sweet orange peel as the rumen filtrate added increased from 1:5 to 5:5. This may have been due to increased fibre and ash, and reduced digestible carbohydrate in the form of nitrogen free extract as the volume of rumen filtrate added to the sweet orange peel for biodegradation increased.

The experimental diets had no significant ($P>0.05$) effect on the FBW, daily BWG, DFI, FCR and daily PI, except PER which significantly ($P<0.05$) increased with higher amount of the rumen filtrate added to the sweet orange peel as shown on Table 3. Rabbits in diet T5, which contained 50% maize replacement with SOP treated with rumen filtrate in ratio 4:5 had a significantly ($P<0.05$) higher PER of 2.10. This result showed that as the quantity of rumen filtrate added to SOP for its biodegradation increased, PER of growing rabbits tended to increase significantly ($P<0.05$). This, most likely stimulated the relatively higher mean final body weight of 1461.40 g of the rabbits in T5 compared to the other dietary treatments.

Table 3: Effect of experimental diets on the performance of grower rabbits

Performance Indices	T1	T2	T3	T4	T5	T6	SEM
IBW (g)	418.33	425.83	425.83	425.83	425.83	376.66	14.78
FBW(g)	1317.00	1338.40	1318.50	1187.00	1461.40	1335.00	32.55
BWG(g)	11.80	12.70	11.76	9.61	12.99	12.46	0.44
DFI(g)	58.88	59.62	61.58	52.58	58.82	53.61	1.64
FCR	5.07	5.45	5.32	5.57	4.56	4.41	0.17
PI(g)	6.19	7.41	6.45	5.79	6.17	6.07	0.20
PER	1.89^{ab}	1.58^{b}	1.61^{b}	1.65^{b}	2.10^{a}	2.07^{a}	0.06

^{ab}Means with different superscripts on the same row are significantly different ($P<0.05$), SEM = standard error of mean, IBW=Initial body weight, FBW=Final body weight, BWG=Body weight gain, DFI=Daily feed intake, FCR=Feed conversion ratio, PI=Protein intake, PER=Protein efficiency ratio.

Table 4: Nutrients Digestibility of grower Rabbits fed diets containing sweet orange (*Citrus sinensis*) peel treated with bovine rumen filtrate

	Experimental Diets						
Parameters	T1	T2	T3	T4	T5	T6	SEM
Dry matter	79.83[a]	60.41[bc]	55.97[c]	72.77[ab]	71.78[abc]	65.97[abc]	4.92
Crude protein	79.12[a]	75.73[ab]	64.92[b]	81.29[a]	81.26[a]	74.41[ab]	3.97
Crude fibre	37.26 [a]	54.97 [a]	44.18 [a]	55.24 [a]	63.37 [a]	53.65 [a]	8.53
Ether extract	88.22[ab]	86.76[bc]	81.49[c]	93.69[a]	91.19[ab]	87.24[b]	1.76
Nitrogen free extract	79.48[a]	67.29[bc]	65.96[c]	76.87[abc]	78.75[ab]	68.48[abc]	3.58

[abc]Means within rows with different superscripts are significantly different (P<0.05), SEM- Standard error mean,
T1= Control Diet (Maize based)
T2= Diets containing 50% biodegraded sweet orange peel as a replacement for maize.
T3= Diets containing 50% biodegraded sweet orange peel as a replacement for maize.
T4= Diets containing 50% biodegraded sweet orange peel as a replacement for maize.
T5= Diets containing 50% biodegraded sweet orange peel as a replacement for maize.
T6= Diets containing 50% biodegraded sweet orange peel as a replacement for maize.

The non-significant (P>0.05) variation of the FBW, BWG, DFI. FCR and daily PI of rabbits irrespective of the dietary treatments, is an evidence of the nutritional potential of biodegraded SOP to serve as a replacement feed resource for maize which is an energy feed ingredient in growing rabbit nutrition. Biodegradation of SOP using bovine rumen filtrate enhanced the nutritive value of SOP for growing rabbit feeding. Thus biodegraded SOP obtained when bovine rumen filtrate is added to SOP in ratio of 1:4 to 5:5 can be used to replace 50% of maize in the diet of growing rabbits. This observation has elicited increased level of utilization of SOP as a replacement for dietary maize at 50% level in the diet of rabbit as against the 30% maize replacement value earlier reported (Oluremi et al., 2018).

The result of the coefficients of digestibility of nutrients by grower rabbits is presented in Table 4. Diets containing biodegraded sweet orange peel had significant (P<0.05) effect on dry matter, crude protein, ether extract, and nitrogen free extract while, the crude fibre did not vary significantly (P>0.05) across the treatment groups. Whereas, the values obtained varied from 55.97% to 79.83% dry matter, 64.92% to 81.29% crude protein, 37.26% to 63.37% crude fibre, 81.49% to 93.69% ether extract, 65.96% to 79.48% nitrogen free extract, none had a particular sequence of variation except crude protein digestibility. Crude protein digestibility range was lower than 78.63% to 84.64% reported by Oluremi et al. (2018) when grower rabbits were fed biodegraded sweet orange peel-based diets. The crude protein digestibility of 81.29% and 81.26% in T4 and T5, respectively were higher than 79.12% in T1 (control dietary group). This suggests a high efficiency in crude protein utilization by rabbits in dietary groups T4 and T5. The crude fibre, dry matter and ether extract values range of 37.26% to 63.37%, 55.97% to 79.83% and 81.49% to 93.69% were lower than 60.48% to 74.72%, 69.49% to 75.41% and 91.93% to 94.79%, respectively reported for grower rabbits fed biodegraded sweet orange peel-based diets (Oluremi et al., 2018). However, nitrogen free extract digestibility coefficient range of 65.96% to 79.48% obtained in this study was similar to digestibility values of 67.48% to 75.54% reported by these authors for growing rabbits fed biodegraded sweet orange peel-based diets. The significant effect (P<0.05) of the experimental diets on the digestibility of dry matter, ether extract and nitrogen free extract showed that the replacement of dietary maize with biodegraded sweet orange peel affected the nutrient quality of diets. While, dietary crude fibre is important for gut motility, digestibility of crude fibre is important in the overall nutrient utilization in rabbit because of the depressive effect it has on the utilization of other nutrients needed for growth and development. The result obtained in the present study did not show that dietary crude fibre caused any adverse effect on rabbit because the live weight of rabbits in T2, T3, T4, T5 and T6 were higher than the live weight of rabbits in T1 (control group).

The bovine rumen filtrate used contained three microbial isolates *Klebseilla* spp., *Escherchia Coli* and *Aspergillus* spp. which possibly improved the feed value of raw SOP treated in ratio of 1 litre RF : 5 kg SOP to 5 litre RF : 5 kg SOP during biodegradation. The FBW, BWG, FI, FCR and PI were similar irrespective of the experimental groups, except PER which increased significantly up to 2.10 when the volume of rumen filtrate added to the sweet orange peel for biodegradation was 4 litre RF : 5 kg SOP (T5). The growth response of rabbits fed biodegraded SOP based diet in ratio 4:5 at 50% maize replacement thus have a comparative advantage over the other treatments and can be used to replace 50% of maize in the diet of growing rabbits.

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Optimization Of Ultrasonic Assisted Extraction Of Bioactive Compounds Of Rumex Acetosella

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Abstract

Aim: This study aims to optimize ultrasonication time, ethanol concentration, and solid-to-solvent ratio for the optimization of the ultrasonic extraction of bioactive compounds from Rumex acetosella. Method: A second-order model for the response variables was developed to obtain quadratic equations. Total phenolic content (TPC) was measured by spectrophotometric absorbance analysis, and the total phenolic compound concentration was calculated as gallic acid equivalent (GAE). Absorbance values were recorded, and calibration curves were generated for analysis. Antioxidant activity (AOA) was evaluated using the DPPH method. The percentage of DPPH radical neutralization was calculated using control and sample absorbance values Results: The quadratic models were significant ($p < 0.05$) with insignificant lack of fit, demonstrating a good fit, and the coefficient of determination values for TPC and AOA were 98.52 and 97.43, respectively. Under optimum process variables of 10 min., 90% ethanol concentration and 0.36 solid-to-solvent ratio, TPC was 692.92 ± 15.38 mg GAE/g, and AOA was 68.50 ± 12.74%. Conclusion: Findings indicate that ultrasound-assisted extraction is an effective method for optimizing the extraction of bioactive compounds from Rumex acetosella, a high total phenolic content (TPC) and antioxidant activity (AOA) under carefully controlled processing conditions. The optimized parameters demonstrated the potential of this technique to maximize the recovery of phenolic compounds and antioxidant properties, making it a promising approach for the extraction of bioactive compounds in food applications.

Key Words: *Ultrasonic Assisted Extraction, Rumex acetosella, Total Phenolic Content, Antioxidant activity, DPPH*

Introduction

Rumex acetosella, commonly known as red sorrel, is a wild plant species that contains important biomolecules and has been traditionally used for various purposes. As time goes by, people are becoming more aware of healthy nutrition, and this complex relationship directs individuals toward foods that contain specific biomolecules for certain metabolic activities (Wen et al., 2018). The components found in R. acetosella are believed to contribute to these characteristics. Its dried upper parts contain rutin, flavone glycosides, hyperin, vitamin C, vitamin A, B complex, carotenoids, chlorophyll, organic acids like oxalic and malic acids, along with various trace elements such as calcium, iron, magnesium, copper, and zinc (Tamayo et al., 2000).

Red sorrel might have different phytonutrient profiles and flavors depending on cultivated area. Some studies suggest that red sorrel species tend to maintain higher antioxidant capacity, richer flavors, and more appealing colors, fragrances, and aromatic compounds (Isbilir & Sagiroglu, 2013). As a result, this study aimed to assess the total phenolic content and antioxidant activity of ethanolic extracts from red sorrels.

The extraction processes of bioactive compounds are of great importance in terms of their utilization. One of the key points to consider in this study is the extraction method. Traditional methods include boiling extraction, Soxhlet extraction, high hydrostatic pressure extraction, and other high-pressure processes. However, these methods have disadvantages in terms of cost, environmental pollution, low efficiency, and time consumption.
In this study, the ultrasonic extraction method was utilized to achieve the most efficient extraction of bioactive compounds from Rumex acetosella. The ultrasonic extraction method we preferred facilitates the breakdown of cell walls and enhances mass transfer by generating cavitation bubbles under pressure. As a result, intracellular components are extracted more efficiently. Moreover, it is referred to as a "green extraction method". Green extraction methods are characterized by low cost, high efficiency, and minimal environmental pollution (Wen et al., 2018).

According to the literature, the optimization of ultrasonic extraction of bioactives from Rumex acetosella hasn't been researched and a comprehensive approach to maximizing the total phenolic content and antioxidant activity has not been explored yet. Therefore, this study aims to optimize ultrasonication time, ethanol concentration and

solid-to-solvent ratio across a wide range of processing conditions to maximize the total phenolic content (TPC) and antioxidant activity (AOA) in Rumex acetosella.

Materials and Methods

Materials

Rumex acetosella was obtained from www.sebzemeyvedunyasi.com. Sodium carbonate, Folin-Ciocalteau (FC) reagent, and 2,2-Diphenyl-1-picrylhydrazyl (DPPH) were purchased from Sigma-Aldrich Chemie Gmbh (Darmstadt, Germany).

Methods

The leaves of Rumex acetosella were washed and left to dry for 7 days. The leaves of Rumex acetosella were separated from the stems. The leaves of Rumex acetosella were powdered with a spice grinder.

Table 1. Experimental Design of Rumex acetosella Powder Extraction with Uncoded Independent Variables, Total Phenolic Content and Antioxidant Activity.

Experimental points	Solid to Solvent Ratio, X1, mg: 20 mL	Ethanol Concentration, X2 %	Ultrasonication Time, X3, min	TPC (Y1), mg GAE/g	AOA(Y2), %
1	0.1	10	20	264,701	68,456
2	0.5	10	20	265,745	39,515
3	0.1	90	20	248,713	87,235
4	0.5	90	20	555,409	65,511
5	0.1	50	10	329,857	63,159
6	0.5	50	10	729,387	17,558
7	0.1	50	30	374,899	73,806
8	0.5	50	30	380,895	10,789
9	0.3	10	10	545,954	51,382
10	0.3	90	10	560,567	71,188
11	0.3	10	30	467,561	53,931
12	0.3	90	30	442,977	79,048
13	0.3	50	20	613,517	38,330
14	0.3	50	20	612,896	32,262
15	0.3	50	20	610,422	38,886
16	0.1	10	20	288,425	68,258
17	0.5	10	20	663,716	54,578
18	0.1	90	20	285,503	87,360
19	0.5	90	20	566,412	73,554
20	0.1	50	10	372,664	67,396
21	0.5	50	10	852,651	35,727
22	0.1	50	30	378,681	62,854
23	0.5	50	30	425,270	14,919
24	0.3	10	10	379,884	64,488
25	0.3	90	10	489,050	80,897
26	0.3	10	30	362,865	63,590
27	0.3	90	30	560,223	80,377
28	0.3	50	20	531,169	67,340
29	0.3	50	20	617,127	41,059
30	0.3	50	20	660,106	39,138

Phenolic content extraction from Rumex acetosella powder was carried out using a 600 W ultrasonic homogenizer (JY92-IIN; Ningbo Scientz Biotech Co Ltd., China).Bioactive compounds were extracted from Rumex acetosella using three different levels of solid-to-solvent ratios (X1), three different levels of ethanol concentrations (X2) and

three different levels of ultrasonication times (X3). A total of 30 ml of solution in a 50 ml beaker was ultrasonicated under each condition. The ultrasound probe was immersed in the solvent up to the safety limit, and a temperature probe was used to maintain the temperature. The ultrasound power was set to 50%, corresponding to 300 W, with a cycle of 2 minutes on and 2 minutes off. After the extraction, the solution was centrifuged at 2000 rpm for 10 minutes.

Total phenolic content (Y1) and antioxidant activity (Y2) were the response variables in this study. A Box Behnken Design was employed due to its suitability for experiments involving three factors, each with three levels. Table 1 presents the actual values of the independent variables across a broad range of operational conditions. Using Box Behnken Design, a second-order model for the response variables was developed to obtain quadratic equations. A total of 30 experimental runs with various combinations were conducted using MINITAB 17.1 (Minitab Inc., State College, PA, USA) to investigate the main and interaction effects (Table 1). Second-order regression equations with coefficients were determined using MINITAB. MINITAB's optimization tool was utilized to determine the optimum conditions for maximizing TPC and AOA.

TPC of Rumex acetosella powder was measured in terms of gallic acid equivalents (GAE mg/g) (Waterhouse, 2002). The supernatant from the extract solution (20 µL) was mixed with 1.58 mL of distilled water and 0.1 mL of Folin-Ciocalteu reagent (0.2 N). After a 3-minute incubation period, 0.3 mL of a 7.5% Na2CO3 stock solution was added. The mixture was then allowed to stand in the dark at room temperature for 1 hours. Absorbance was measured at 765 nm using a spectrophotometer (T80+, UV/Vis spectrometer, PG Instrument Ltd.) in triplicate.
The AOA of ultrasonic-assisted extracts of Rumex acetosella powder was evaluated using the percent DPPH radical inhibition method (González-Aguilar et al., 2007), with slight modifications. The extract (0.1 mL) was mixed with 3.9 mL of a DPPH solution (0.6 mM in 80% ethanol). The mixture was kept in the dark for 60 minutes. Absorbance was then measured at 517 nm using a spectrophotometer. The antioxidant activity percentage (AOA%) was calculated using the following equation.

$$\text{AOA}\ (\%) = \frac{A_{DPPH} - A_{Sample}}{A_{DPPH}} * 100$$

Results and Discussion

Effects of different Parameters on TPC

Table 2. Effects of Sorrel (*Rumex acetosella* L.) Extraction Parameters on TPC

Parameter	TPC Coefficient	TPC P values	AOA Coefficient	AOA P values
Intercept	585.9	<0.001	43.09	<0.001
Solid-Liquid Ratio(X_1)	145.3	<0.001	-16.65	<0.001
Ethanol Conc.(X_2)	11.7	0.509	10.31	<0.001
Time (X_3)	-45.1	0.018	-1.03	0.664
X_1^2	-74.2	0.010		
X_2^2	-96.9	0.001	25.25	<0.001
X_1X_3	-85.1	0.004	-8.42	0.217
Model p-value	<0.001		0.000	
R^2	85.28%		83.96%	
Adjusted R^2	80.87%		80.61%	

Table 3. Optimum Conditions and TPC Values

Parameter	Optimum Value
Ethanol Concentration	90%
Solid to Liquid Ratio	0.36 mg/20 mL
Ultrasonication time	10 min.
TPC(mg GAE/g)	692.92 ± 15.38
AOA(%)	68.50 ± 12.74%

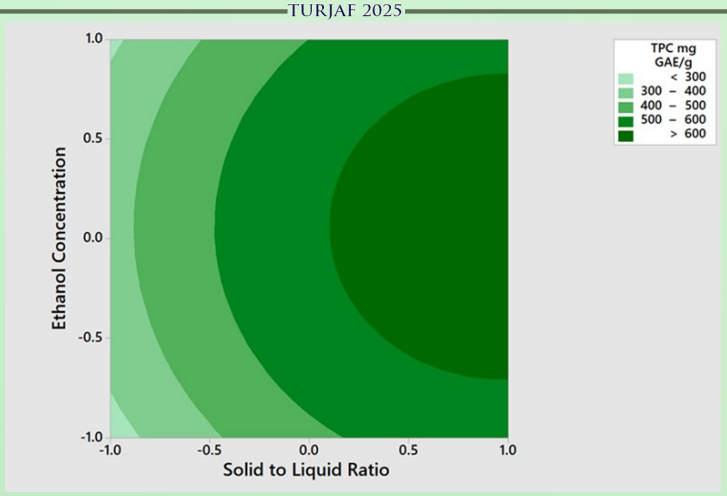


Figure 1. Contour Plot of TPC (mg GAE/g) as a Function of Ethanol Concentration and Solid-to-Liquid Ratio in Rumex acetocella L. Extract

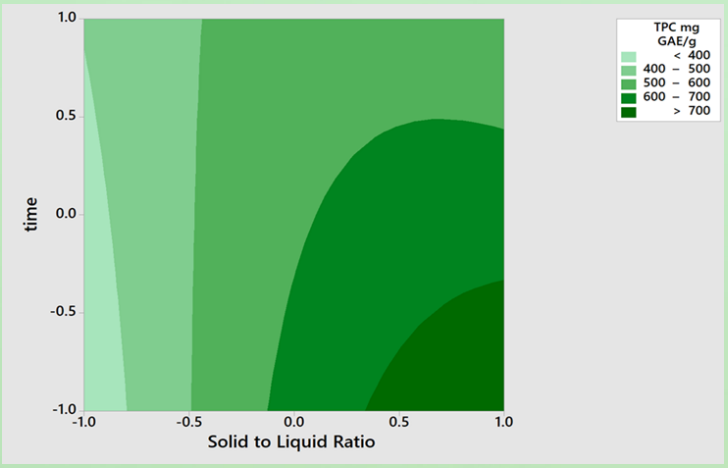


Figure 2. Contour Plot Analysis of Total Phenolic Content (TPC) Expressed as mg GAE/g: The Influence of Time and Solid-to-Liquid Ratio

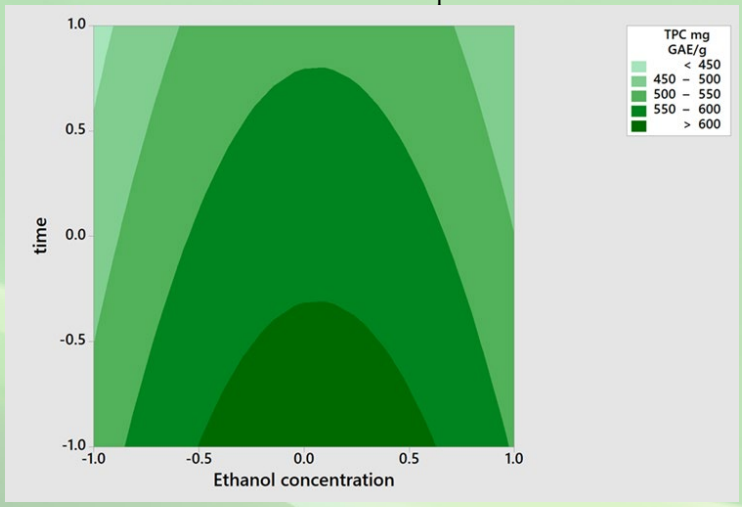


Figure 3. Contour Plot of Total Phenolic Content (TPC) in mg GAE/g: Effects of Time and Ethanol Concentration

Effect of ethanol concentration on TPC

The contour plots (Figures 1 and 3) clearly demonstrate the relationship between ethanol concentration and TPC. The graphs show that TPC values varied between 450-600 mg GAE/g corresponding to coded ethanol concentration levels ranging from -1.0 to +1.0 (equivalent to 10-90% actual concentration). The optimum TPC values (>600 mg GAE/g) were obtained at high ethanol concentrations.

The data in Table 2 show that the linear term of ethanol concentration (X_2) was statistically insignificant (p=0.509). This finding is consistent with the observation in the contour plots that variations along the ethanol axis did not

produce a linear effect on TPC. Similarly, Bouafia et al. (2021) reported that wide ethanol concentration ranges may not be suitable for optimization.

In contrast, the quadratic term (X_2^2) in Table 2 showed a highly significant effect (p=0.001), indicating that ethanol concentration has a non-linear (quadratic) influence. This result is supported by the parabolic trends observed in the contour plots, demonstrating that ethanol reduces extraction efficiency beyond a certain optimal concentration range (80-90%). Similar non-linear relationships have been reported in studies on Tartary buckwheat hull extraction by Dzah et al. (2020).

Under the optimal conditions presented in Table 3, the ethanol concentration was determined to be 90%. This value corresponds to the moderate-performance region in the contour plots and is consistent with the 80-90% ethanol concentration range recommended for phenolic compound extraction from grape seeds by Ghafoor et al. (2009).

Effect of solid-liquid ratio on TPC

This study determined that the solid-to-liquid ratio (X_1) exhibited a highly significant effect on TPC ($p < 0.001$). The positive regression coefficient (145.3) demonstrated a linear enhancement of TPC with increasing solid-to-liquid ratio.

Contour plot analyses (Figure 2) revealed that maximum TPC values (>600 mg GAE/g) were achieved at high solid-to-liquid ratios (0.36 mg/20 mL) combined with moderate ultrasonication durations (~23 min). These results align with findings by Ghafoor et al. (2009) for grape (*Vitis vinifera*) seed extraction. However, the significant negative quadratic term (X_1^2: -74.2, $p = 0.010$) suggested reduced extraction efficiency at excessively high ratios (>5 mg/10 mL), indicating an optimal range for solid loading.

A significant negative interaction between solid-to-liquid ratio and time (X_1X_3, $p = 0.004$) was observed. This suggests that prolonged extraction at high solid loading may promote release of undesirable compounds, potentially due to cell wall degradation. Similar findings were reported by Bouafia et al. (2021) for *Centaurea* sp. phenolic extraction.

Under optimized conditions (solid-to-liquid ratio: 0.36 mg/20 mL), the predicted maximum TPC reached 692.92 ± 15.38 mg GAE/g. This value substantially exceeds the 592 mg GAE/g reported by Dzah et al. (2020) for Tartary buckwheat (*Fagopyrum tataricum*) hull extracts, likely due to fundamental differences in the cell wall matrix and phenolic composition of *Rumex acetosa*. Moreover, the total phenolic content of wild and cultivated sheep sorrel was measured at 69.21 ± 8.5 (İsbilir and Sağıroğlu, 2013), which is lower than our findings, indicating that ultrasonic extraction yields more phenolic content than room temperature extraction.

Effect of time on TPC Levels

Statistical analysis revealed that ultrasonication time (X_3) significantly affected total phenolic content (TPC) (p=0.018). The regression analysis demonstrated a negative correlation between ultrasonication duration and TPC levels ($\beta = -45.1$), indicating that prolonged ultrasonication leads to degradation of phenolic compounds.

As evident from Figure 3, maximum TPC values (>550 mg GAE/g) were obtained at extraction durations of 15-20 minutes. During the initial 0-15 minute period, TPC levels increased substantially due to cavitation-induced cell wall disruption and subsequent rapid diffusion of phenolic compounds. However, with increasing extraction time and concomitant temperature elevation, thermal degradation and oxidative reactions of phenolic compounds resulted in a plateau phase (15-25 minutes) followed by a marked decline in TPC levels beyond 25 minutes, attributable to dynamic equilibrium between extraction and degradation processes. This trend was consistent with observations reported by Alonso-Riaño et al. (2020) in their study on brewer's spent grain extracts.

Effects of different Parameters on AOA

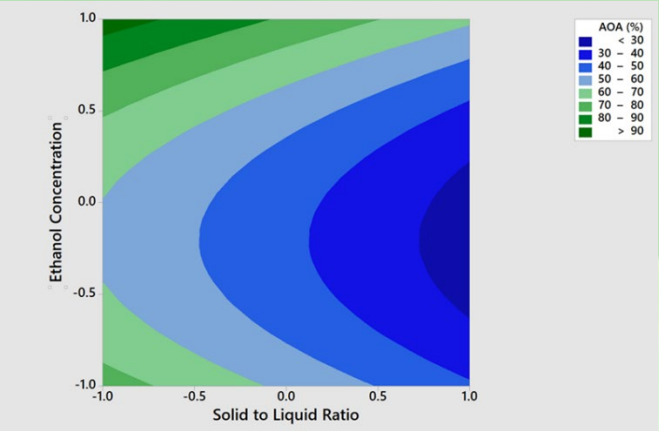


Figure 4. Contour Plot of Antioxidant Activity (AOA) in %: Effects of Ethanol Concentration and Solid-to-Liquid Ratio

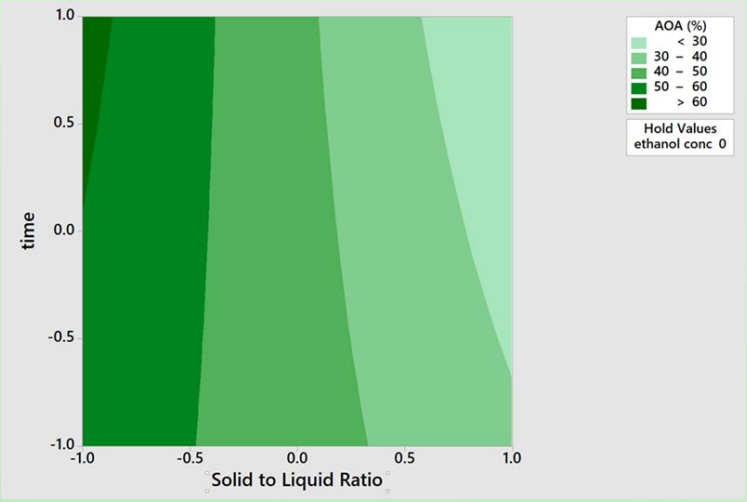


Figure 5. Contour Plot of Antioxidant Activity (AOA) in %: Effects of Extraction Time and Solid-to-Liquid Ratio

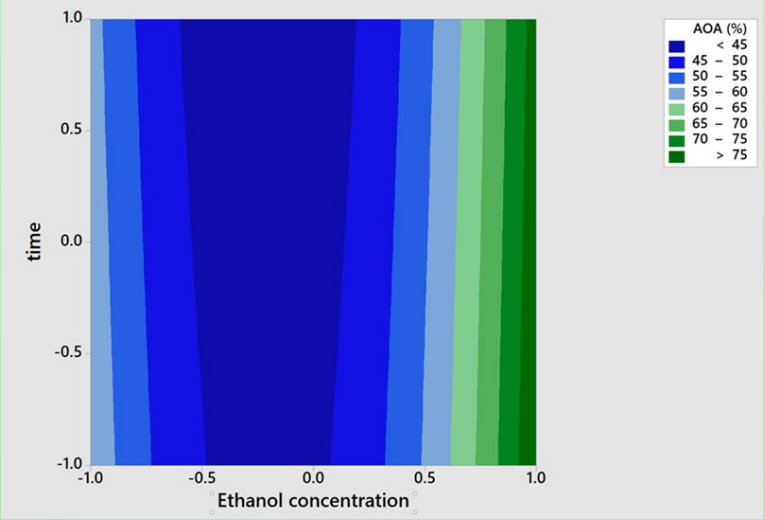


Figure 6. Contour Plot of Antioxidant Activity (AOA, %): Interaction Effects of Extraction Time and Ethanol Concentration

Effect of time and ethanol concentration on antioxidant activity

The current research investigated the sensitivity of *Rumex acetosella* antioxidant activity (AOA) levels to ethanol concentration and extraction times. The influence of ethanol concentration on antioxidant activity was not linear. Notably, the maximum AOA values recorded (68.49%) were at an ethanol concentration of 90%, as indicated in Figures 4 and 6. The reason being that elevated levels of ethanol enhance solubility, and thereby the efficiency of lipophilic phenolic compounds' extraction (Irfan et al., 2022). Yet, further increase in ethanol concentration beyond a certain level can make antioxidant compounds less stable, thereby lowering their antioxidant activity.

In terms of extraction time, it was observed that greater activity values were obtained in a shorter duration of 10 minutes than in longer durations of 30 minutes. This observation highlights the capacity of ultrasonication to break down cell structures quickly, thereby facilitating efficient extraction of antioxidant compounds (Muñiz-Márquez et al., 2013). The reduction of antioxidant activity in longer extraction is attributed to thermal degradation and oxidative degradation processes.

The highest AOA values were achieved in experiments conducted in optimal conditions with the 10-minute extraction time and 90% ethanol concentration. These results demonstrate the complex interaction of plant material's chemical composition and ultrasonic extraction parameters. The pattern of nonlinear behavior is thought to be a result of antioxidants' varying polarities and the varying effect of this polarity difference on extraction efficiency.

Effect of time and solid-liquid ratio on antioxidant activity

Influence of time and solid-to-liquid ratio on antioxidant activity. This research examined the influence of extraction time and solid-to-liquid ratio on the antioxidant activity (AOA) of *Rumex acetosella* extracts. From the contour plot analysis, it was noted that high antioxidant activity values of 65% to 70% can be attained at short extraction times of just 10 minutes. This can be explained by the fact that ultrasonication has a cavitation effect that quickly ruptures cell walls, thereby facilitating the extraction of antioxidant compounds effectively (Alara et

al., 2021). However, when the extraction time was increased to 30 minutes, there was a 10–15% decrease in AOA, suggesting that prolonged ultrasonication may demolish thermolabile antioxidant compounds (Zhou et al., 2022). Under the evaluation of the solid-liquid ratio's effect on AOA, the highest values of activity were registered at a high solid-liquid ratio of 0.36g/20mL. The findings show that a suitable solid-liquid ratio greatly improves the efficiency of extraction (Wang et al., 2023). Conversely, a low ratio of 0.36 g/20 mL (1:55.50) caused a precipitous drop in AOA due to the dilution effect of antioxidant compounds by an excess of solvent. The analysis of parameter interactions showed that the best AOA values were obtained through the combination of a 10-minute extraction time and 0.36g/20mL solid-liquid ratio. The optimal conditions described above utilize the benefits of ultrasonic extraction to achieve maximum time and solvent efficiency (Alara et al., 2021). The results emphasize the importance of optimizing time and solid-liquid ratio in the extraction process of antioxidant compounds from *Rumex acetosella*. The optimal conditions developed are of great importance as reference standards for application at the industrial level.

Effect of ethanol concentration and solid-liquid ratio on antioxidant activity

In the present research, it was investigated how changing the relationship between extraction parameters, ethanol concentration and solid-liquid ratio on the antioxidant activity of *Rumex acetosella* extracts. Figure 4 demonstrates a 1:15 ratio. These findings can be explained by the solubility of lipophilic phenolics at higher ethanol concentrations and the maximum extraction efficiency obtained with the optimum solid-liquid ratio (Ziani et al., 2023).Notably, ethanol concentration exceeded 90% AOA decreased by 12-15% which may be explained by ethanol-induced denaturation of cellular structures and subsequent breakdown of heat-sensitive bioactive components (Rajha et al., 2014).

The results showed that the highest antioxidant activity was obtained using a 1:55.5 extraction ratio (0.36g/20mL).This suggests that an adequate solvent volume ensures complete extraction of bioactive compounds while preventing excessive dilution (Rajha et al., 2014) Conversely, the 1:50 ratio (0.2 g/20 mL) yielded only 45.3% AOA attributable to the dilution effect caused by disproportionate solvent volume on antioxidant compounds.

Maximum AOA was observed 10 min extraction time with 90% ethanol at a 1:55.5 solid-liquid ratio. These conditions maximized ultrasonic cavitation, which efficiently fractured cell membranes and released antioxidant components at higher yields (Ziani et al., 2023).

However, extending the extraction time to 30 min resulted in an 18% decrease in AOA, suggesting that prolonged ultrasonication may destabilize antioxidant compounds.

This study systematically optimized three critical extraction parameters ethanol concentration, solid-liquid ratio, to maximize total phenolic content and antioxidant activity in *Rumex acetosella*. Optimal extraction conditions (90% ethanol, 1:55.5 ratio, 10 min) TPC values were measured as 692.92 ± 5.34 mg GAE/g. This observation is consistent with the findings of Irfan et al. (2022) that ethanol concentrations exceeding 90% cause degradation of heat-labile phenolics through denaturation of plant cell matrices. For AOA, maximum activity (68.49%) was obtained with short ultrasonication time (10 minutes) and a high solid-liquid ratio (0.36g/20ml). Ultrasonic waves produce microbubbles that mechanically disrupt cellular structure senabling efficient extraction of intact lipophilic antioxidants (Ziani et al., 2023). The composite desirability value (D=0.7445) indicated a balanced optimization of both TPC and AOA. However, the wide range of prediction for TPC (529.1–856.8 mg GAE/g) indicates the critical necessity for stringent control over process parameters. As it stands, therefore, the optimized condition (90% ethanol, 1:55.5 ratio, 10 min) offers a promising platform for extraction at the industrial level, with a green production strategy by reduced solvent usage (40% less than conventional) and shorter processing time (50% less).

Conclusion

This study explored the optimization of ultrasound-assisted extraction for enhancing the total phenolic content (TPC) and antioxidant activity (AOA) of Rumex acetosella (Sorrel). The results revealed significant relationships between extraction parameters, including ethanol concentration, solid-liquid ratio, and extraction time, on both TPC and AOA. Notably, ethanol concentration had a non-linear effect on TPC, with the highest phenolic content achieved at 90% ethanol. The solid-to-liquid ratio demonstrated a significant linear effect, where higher ratios (0.36 g/20 mL) led to enhanced extraction efficiency. Ultrasonication time was found to significantly influence TPC levels, with a peak at 10-20 minutes, after which degradation occurred. The optimized extraction conditions—90% ethanol, 1:55.5 solid-liquid ratio, and 10 minutes ultrasonication—produced TPC values of 692.92 ± 15.38 mg GAE/g and an AOA of 68.50%, presenting significant improvements over traditional methods. The findings underscore the potential for scaling this optimized process in industrial applications, contributing to a greener, more efficient extraction strategy by reducing solvent usage and extraction time. Future research should focus on further validating these optimized conditions in large-scale industrial applications, particularly for the extraction of bioactive compounds from other plant materials. Additionally, studies could explore the stability and bioavailability of the encapsulated phenolic compounds in food or pharmaceutical products. Investigating the impact of other extraction methods, such as supercritical fluid extraction, on the yield and quality of phenolic compounds, could offer a comparative perspective. Finally, the development of more sustainable and cost-effective extraction techniques should be prioritized, including the use of green solvents or waste-reducing technologies.

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ID: 573

Evaluation of Individual Groundwater (GW) Irrigation in the Konya Closed Basin in Terms of Energy Consumption and Greenhouse Gas Emissions

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Abstract

Konya Closed Basin is one of the 25 hydrological basins in Turkey. Individual groundwater irrigations in the basin have the highest ratio compared to other groundwater and surface water irrigations in terms of both irrigation area and agricultural water use. The number of individual irrigation wells in the basin is 74,621, with a total irrigation area of 414,209 hectares. In this study, individual groundwater irrigations in the Konya Closed Basin were evaluated in terms of energy consumption and greenhouse gas emissions for the years 2010, 2015 and 2020. Total energy consumption in individual groundwater irrigations was calculated as 12.875.442.516,8 MJ/year in 2010, 16.005.581.706,3 MJ/year in 2015 and 25.424.556.672,6 MJ/year in 2020. The amount of energy per unit area (E_A) was calculated as 31.084,4 MJ/ha, 38.641,3 MJ/ha and 61.381,0 MJ/ha in total for the years 2010, 2015 and 2020, respectively. The amount of energy per unit irrigation water (E_S) was 6,146 MJ/m^3 in 2010, 7,497 MJ/m^3 in 2015 and 11,691 MJ/m^3 in 2020. Total emissions from irrigation were calculated as 695.123.598,9 kgCO_2eq/year in 2010, 864.114.576,6 kgCO_2eq/year in 2015 and 1.372.629.275,6 kgCO_2eq/year in 2020. The emission amount per unit area (SG_A) was determined as 1.678,2 kgCO_2eq/ha, 2.086,2 kgCO_2eq/ha and 3.313,9 kgCO_2eq/ha for 2010, 2015 and 2020, respectively, while the emission amounts per unit irrigation water (SG_S) were determined as 0,332 kgCO_2eq/m^3, 0,405 kgCO_2eq/m^3 and 0,631 kgCO_2eq/m^3 for the same years, respectively. As a result of the evaluation, it is seen that energy consumption and greenhouse gas emissions in individual groundwater irrigation have increased over the years, with an approximately two-fold increase in 2020 compared to 2010.

Key Words: *Energy consumption, Konya Closed Basin, Greenhouse gas emission, Groundwater (GW) Irrigation*

Konya Kapalı Havzası Bireysel Yer altı (YAS) Sulamalarının Enerji Tüketimi ve Sera Gazı Emisyonu Yönünden Değerlendirilmesi

Özet

Konya Kapalı Havzası, Türkiye'deki 25 hidrolojik havzadan bir tanesidir. Havzada yer alan bireysel YAS sulamaları hem sulama alanı, hem de tarımsal su kullanımı açısından, diğer yer altı ve yer üstü sulamalarına oranla en yüksek orana sahiptir. Toplam 414.209 ha'lık sulama alanı ile birlikte, havzadaki şahıs kuyularının sayısı 74.621'dir. Bu çalışmada, Konya Kapalı Havzasında yer alan bireysel YAS sulamaları 2010, 2015 ve 2020 yılları için, enerji ve sera gazı emisyonu bakımından değerlendirilmiştir. Bireysel YAS sulamasında toplam enerji tüketimleri, 2010 yılında 12.875.442.516,8 MJ/yıl, 2015 yılında 16.005.581.706,3 MJ/yıl ve 2020 yılında 25.424.556.672,6 MJ/yıl olarak hesaplanmıştır. Birim alana karşılık enerji miktarı (E_A), 2010, 2015 ve 2020 yılları için sırasıyla toplam, 31.084,4 MJ/ha, 38.641,3 MJ/ha ve 61.381,0 MJ/ha olarak hesaplanmıştır. Birim sulama suyuna karşılık enerji miktarı ise (E_S), 2010 yılında 6,146 MJ/m^3, 2015 yılında 7,497 MJ/m^3 ve 2020 yılında 11,691 MJ/m^3 olmuştur. Sulamadan kaynaklanan toplam emisyon miktarları ise, 2010 yılında 695.123.598,9 kgCO_2eşd/yıl, 2015 yılında 864.114.576,6 kgCO_2eşd/yıl ve 2020 yılında 1.372.629.275,6 kgCO_2eşd/yıl olarak hesaplanmıştır. Birim alana karşılık emisyon miktarı (SG_A), 2010, 2015 ve 2020 yılları için sırasıyla, 1.678,2 kgCO_2eşd/ha, 2.086,2 kgCO_2eşd/ha ve 3.313,9 kgCO_2eşd/ha, birim sulama suyuna karşılık emisyon miktarları ise (SG_S), aynı yıllar için sırasıyla 0,332 kgCO_2eşd/m^3, 0,405 kgCO_2eşd/m^3 ve 0,631 kgCO_2eşd/m^3 olarak belirlenmiştir. Değerlendirme sonucunda, bireysel YAS sulamalarında enerji tüketimi ve sera gazı emisyonlarının yıllara bağlı olarak arttığı, 2020 yılında 2010 yılına kıyasla yaklaşık iki kat artışın olduğu görülmektedir.

Anahtar Kelimeler: *Enerji tüketimi, Konya Kapalı Havzası, Sera Gazı Emisyonu, Yer altı (YAS) Sulaması*

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The Effect of Solid-State Fermentation using *Aspergillus niger* on the Nutritional Composition of Grape Seed, Cherry Kernel, and Maize Seed Mixture

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Abstract

The effect of solid-state fermentation using *Aspergillus niger* strains on the nutritional composition of the mixture of grape seed, cherry kernel, and maize seed was investigated in this study. Fermentation substrate consisting of 40 g of grape seeds, 40 g of cherry kernel, and 20 g of maize was fermented by *A. niger* strains (ATCC 200344, 200345, 201572, 52172). The substrate was enriched with a nutrient medium and sterilized with an autoclave. Each strain of *Aspergillus niger* was inoculated with 10^6 spores into the substrate. Incubation was carried out for seven days at 30 °C. Crude protein, ether extract, ash, nitrogen-free extract, and crude fiber contents of substrate were determined before and after fermentation. Solid-state fermentation using *A. niger* increased ($P<0.001$) crude protein content of the substrate. In addition, the ether extract content of the substrate was increased ($P<0.001$) by *A. niger*. Similarly, *A. niger* increased ($P=0.001$) the ash content of the grape seed, cherry kernel, and maize mixture. However, crude fiber was declined ($P<0.001$) by fermentation using *A. niger*. Similarly, solid-state fermentation decreased the nitrogen-free extract of the substrate. The obtained results showed that solid-state fermentation using *A. niger* can improve the nutritional composition of the mixture of grape seed, cherry kernel, and maize seed.

Key Words: *Solid-state fermentation, Aspergillus niger, Grape seed, Cherry kernel, Corn seed*

ID: 575

İklim ve Arazi Örtüsü Değişikliği Bağlamında Havza Ölçeğinde Gelecekteki Toprak Erozyonun Tahmini

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Özet

Yaşam sürdüğümüz çevrede var olan antropojenik faaliyetler doğanın kendi içerisindeki işleyişi etkilemektedir. Bu etkiler doğal süreçlerin olması gerekenden daha hızlı veya daha yavaş olmasına yol açarak çeşitli olumsuzluklar yaratmaktadır. Özellikle artan nüfus ve kentleşmeye bağlı arazi kullanım arazi örtüsünde meydana gelen değişimlerin yanında küresel bir sorun olan iklim değişikliği gibi faktörler doğal sistemlerde dönüşü olmayan olumsuzluklar ve kayıplar oluşturmaktadır. Bu olumsuzluklar yer yüzünde yaşam sağlayan canlıların besin kaynağını oluşturan alanları da doğrudan ya da dolaylı olarak etkilemektedir. Bu bağlamda yer yüzünde var olan doğal kaynakların korunması, gelecek yıllardaki olası durumlarının araştırılması önem arz etmektedir. Bu nedenle canlıların besin kaynaklarının temelini oluşturan verimli toprakların erozyona bağlı olarak gelecekte nasıl etkileneceğinin araştırılması çalışmanın amacını oluşturmaktadır. Bu amaç doğrultusunda dünyada ve ülkemizde oldukça fazla kullanılan RUSLE modeli aracılığıyla Meriç-Ergene Havzasında meydana gelebilecek potansiyel erozyon durumları CBS ortamında analiz edilmesi ve haritalandırılması hedeflenmiştir. Bu amaç ve hedef doğrultusunda çalışma 3 aşamalı bir yöntem dahilinde yürütülmüştür. Birinci aşamada; CMIP6 iklim modellerinden alınan SSP 2-4.5 (Orta) senaryo verileri aracılığıyla gelecekte meydana gelecek yıllık ortalama yağış miktarı haritalası 2050 yılı için coğrafi bilgi sistemleri aracılığıyla haritalandırılmıştır. İkinci aşamada; ESRİ tarafından sağlanan küresel AKAÖ verileri kullanılarak (2017-2023) 2050 yılında meydana gelebilecek AKAÖ haritası Gelecekteki Arazi Kullanımı Simülasyonu (FLUS) modeli aracılığıyla üretilmiştir. Üçüncü aşamada ise; . Uzaktan Algılama (UA) ve Coğrafi Bilgi Sistemleri (CBS) teknolojileri ile desteklenen ve alt faktörün (R, K, L, S, C ve P faktörleri) bileşiminden oluşan Revize Edilmiş Evrensel Toprak Kayıp Denklemi (RUSLE) kullanılarak Günümüz ve 2050 yılında meydana gelebilecek potansiyel erozyon miktarı analiz edilmiş ve haritalandırılmıştır. Yapılan analiz sonucunda iklim değişikliği ve AKAÖ değişimlerinin potansiyel erozyon miktarını ve şiddetini etkilediği tespit edilmiş olup, buna yönelik öneriler ortaya konulmuştur. Bu çalışmanın çıktıları özellikle iklim değişikliği ve AKAÖ değişikliğine bağlı olarak gelecekte meydana gelecek potansiyel kayıpların önceden tespit edilmesi, alternatif önleme çözümlerinin geliştirilmesi ve sürdürülebilir arazi yönetimi konularına önemli katkılar sağlayacaktır.

Key Words: *Meriç-Ergene, İklim Değişikliği, RUSLE, Erozyon, Uzaktan Algılama.*

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Skin Diseases in Beekeepers: Causes and Risk Factors

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Abstract

Beekeeping is a labor-intensive profession that necessitates constant exposure to outdoor environmental conditions. As a result, beekeepers are frequently subjected to various physical and chemical agents, which can lead to dermatological conditions such as eczema. Eczema is a chronic inflammatory skin disorder characterized by redness, itching, dryness, and blister formation. One of the primary occupational risk factors for eczema in beekeepers is prolonged contact with bee products—including honey, propolis, and beeswax—which can trigger allergic reactions. Despite its potent antibacterial properties, propolis is a well-known contact allergen that may cause allergic contact dermatitis in sensitized individuals. Working conditions also significantly contribute to eczema development. Beekeepers often wear boots, gloves, and protective suits for extended periods, leading to sweating and sustained skin moisture, which can aggravate irritation and inflammation. Prolonged exposure to heat and sunlight may further weaken the skin barrier and increase sensitivity. Additionally, inadequate hygiene or improper sanitation practices, along with frequent use of chemical repellents and disinfectants to prevent bee stings, may exacerbate skin damage. Excessive use of soaps and detergents can deplete the skin's natural oils, increasing dryness and susceptibility to eczema. This paper discusses the etiology, risk factors, clinical symptoms, and diagnostic approaches for occupational eczema among beekeepers. Furthermore, it outlines preventive strategies such as proper use of personal protective equipment, skin care routines, and treatment options. Recommendations for minimizing occupational skin diseases in the beekeeping sector are also provided.

Keywords: *Beekeeping, propolis, allergic contact dermatitis, occupational health, eczema*

Introduction

Due to its ecological diversity and socio-economic structure, beekeeping is practiced in almost every region of Turkey. Although approximately 75% of the world's nectariferous plants grow in Turkey, only about 10% of this potential is currently utilized (Doğanay, 2007). Turkey ranks second globally in honey production with about 7% of the total share and third in terms of colony numbers (Güneşdoğdu & Akyol, 2019). The country's favorable climate and rich natural flora offer a suitable environment for beekeeping (Güneşdoğdu & Şekeroğlu, 2020).
However, beekeeping involves significant occupational hazards due to both physical and chemical exposure. Beekeepers are at higher risk of developing dermatological diseases, particularly eczema and contact dermatitis, due to frequent contact with bee products and the chemicals used in pest management.

Dermatological Risk Factors in Beekeeping

Propolis, a natural compound collected by bees from various plants, is a common allergen that may cause contact sensitivity (Bunney, 1986). The reported prevalence of allergic reactions to propolis ranges from 1.2% to 6.6% (Münstedt & Kalder, 2009). Geographic variation in its chemical composition complicates the evaluation of contact allergies (Nyman et al., 2020). Beekeepers also use acaricides containing formic acid, oxalic acid, and essential oils such as thyme, lavender, and bay leaf to control parasitic mites. These substances are known to be irritant and allergenic (Qayoom et al., 2024).
Dermatitis is a common inflammatory skin disorder caused by disruption of the skin barrier due to chemical or physical agents (Uter et al., 1998). Pathophysiologically, it is classified into irritant contact dermatitis (ICD) and allergic contact dermatitis (ACD). ACD arises from an acquired immune response to specific antigens, while ICD results from activation of the innate immune system by irritant substances (Krasteva et al., 1999a).
Frequent use of soap and disinfectants weakens the skin barrier, potentially leading to hand eczema. Symptoms include itching, dryness, fissures, and bleeding (Singh et al., 2020). If left untreated, eczema may worsen over time and negatively affect the patient's quality of life (Agner et al., 2008; Techasatian et al., 2021).

Prevalence and Prevention of Eczema in Beekeepers

Due to regular exposure to substances like propolis, beeswax, bee venom, and acaricides, beekeepers often develop compromised skin barriers. While protective equipment such as gloves and masks can reduce contact with irritants, prolonged use may cause sweating and further irritation.



Figure 1. ChatGPT-Assisted Scientific Illustration: Pathogenesis of Occupational Eczema and Associated Skin Lesions in Beekeepers.

Living conditions also influence eczema risk. Beekeepers in rural areas may face limited access to hygiene facilities, which hinders proper skin care. Inadequate laundering of clothing may contribute to bacterial or fungal infections, worsening eczema.

Heat and perspiration are additional risk factors. Sweat disrupts the skin barrier, promoting irritation and microbial growth. Therefore, it is recommended that beekeepers wear breathable cotton clothing, cleanse their skin after sweating, and wash garments regularly. A visual representation of eczema lesions and etiological factors generated by an AI tool (ChatGPT) is provided in Figure 1.

Oosterhaven et al. (2019) reported a one-year prevalence of dermatitis among Dutch beekeepers at 13.2%, with a lifetime prevalence of 20.5%. The development of allergic sensitivity to propolis typically requires about 9.5 years of occupational exposure (Münstedt & Kalder, 2009). Illg and Sanokowska (1976) documented a 4.04% prevalence of propolis-induced allergy in Polish beekeepers. Among the 26 allergens identified in propolis, the most significant is LB-1, which contains three pentenyl caffeate esters derived from poplar buds. These include 3-methyl-2-butenyl caffeate (54.2%), 3-methyl-3-butenyl caffeate (28.3%), and 2-methyl-2-butenyl caffeate (4.3%), as well as phenethyl caffeate (7.9%), caffeic acid (1.3%), and benzyl caffeate (1.0%). Other compounds such as caffeic acid phenethyl ester (CAPE), benzyl salicylate, and benzyl cinnamate also contribute to contact dermatitis (Basista-Sołtys, 2013).

To mitigate the risk of eczema and related skin conditions, beekeepers should wear appropriate protective clothing, adhere to hygiene practices, and minimize contact with irritant substances. Regular skin care and medical checkups are also advised. Figure 2 illustrates eczema-related lesions on the hands, feet, knees, and scalp of beekeepers.

Conclusion and Recommendations

Etiological factors of eczema:

1. Genetic predisposition, immune responses, and environmental conditions.
2. Continuous exposure to bee products and external elements places beekeepers in a high-risk category.

Preventive measures:

1. Use protective gloves and suitable clothing.
2. Maintain regular skin care using non-irritating moisturizers.
3. Avoid contact with harsh chemicals and detergents.
4. Prefer dermatologically appropriate products over regular soaps.



Figure 2. Clinical Manifestations of Occupational Eczema in Beekeepers Across Different Body Regions

Recommendations for beekeepers:

1. Implement measures to reduce allergen exposure in the workplace.
2. Choose latex-free, breathable gloves.
3. Keep headgear and underarm areas clean, as they accumulate sweat.
4. If boots are worn for foot protection, they should be cleaned regularly.
5. Choose apiary locations near water sources and launder clothing frequently.
6. Prioritize personal hygiene.
7. Seek dermatological care at the early signs of eczema.
8. Suggestions for future research:
9. Conduct large-scale epidemiological studies on the prevalence of eczema in beekeepers.
10. Examine the dermatological effects of bee products in detail.
11. Develop effective and natural preventive solutions for eczema.

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Nutrient Balance and Efficiency in Agricultural Activities and Greenhouse Gas Emissions from Nutrients and Crops

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Abstract

Agricultural activities play a crucial role in food production; however, excessive use of synthetic fertilizers has raised serious concerns regarding soil, water, and environmental pollution. Nutrient deficiency, how well crops use available nutrients and how effectively agricultural inputs (synthetic fertilizers, manure applied to soils, nitrogen deposition, biological fixation and seed) are applied have gained importance. Therefore, the study analyzes cropland nutrient balance, nutrient use efficiency and greenhouse gas emissions from synthetic fertilizers and crops in Turkiye. Data is retrieved from FAOSTAT (Food and Agricultural Organization of the United Nations) for the 1961-2022 period. This article also proposes sustainable alternatives to mitigate adverse effects, emphasizing the need for balanced agricultural practices to ensure agricultural and environmental sustainability. An increasing N surplus and increasing K deficit was found, which can be explained by higher increase in crop removal than mineral fertilizers. Nitrogen use signaled for possible deficiency due to efficiency falling below the treshold. Quantity of cereal production explained 93% of the variability in total N2O GHG emissions. N2O emissions from cereals were not significantly different from CH4 emissions from rice cultivation in 2022. Although nutrious dioxide emission intensity had a logaritmic trajectory, variations were high in the last decade. Overall, greenhouse gas emissions from fertilizers and cereals are in desired levels despite some risks for nitrogen and potassium deficiencies. N interventions and altering composions of fertilizers should be promoted to balance crop removal and mineral fertilizers. Future studies should consider greenhouse gas emmisions from pesticide use in relation to environmental effects. Farmers in Türkiye should adopt sustainable agricultural practices such as use of organic fertilizers; precision agriculture techniques to optimize fertilizer application; and crop rotation and cover crops to maintain soil health and prevent nutrient depletion. Policymakers and farmers must collaborate to promote these practices through education, incentives, and regulatory frameworks.

Key Words: *Nutrient balance, Nutrient efficiency, Greenhouse gas emissions, Turkiye*

ID: 578

Antifungal Activity of Methanol Extracts Obtained from *Verbascum* L. (Mullein) Species Collected from Different Regions Against *Rhizoctonia solani*

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Abstract

Plants are among the important natural resources preferred in combating plant pathogens due to their secondary metabolites. In this study, the antifungal effects of methanol extracts obtained from regional *Verbascum* (Mullein) species collected from ecologically different locations (Karasu, Konya, Bolu, Arifiye, and Manisa) were investigated under *in vitro* conditions against *Rhizoctonia solani* (J.G. Kühn), a soil-borne phytopathogenic fungus with a wide host range. For this purpose, methanol extracts were obtained from the flower and leaf parts of *Verbascum* species, and the potential of these extracts at different concentrations (0.5%, 1%, 2%, and 4%) to inhibit mycelial growth in the culture medium was evaluated. All tested extracts exhibited antifungal activity at varying levels. The extract prepared from samples collected in Konya showed the highest inhibition of mycelial growth, suppressing it by 55%. This was followed by the extract from Karasu with an inhibition rate of 45%. Extracts obtained from other locations exhibited antifungal activity at varying degrees, inhibiting mycelial growth between 7.5% and 36.25%. The findings indicate that methanol extracts obtained from *Verbascum* species exhibit antifungal activity against *Rhizoctonia solani* and that this effect increases with the applied dose. These results suggest that the active compounds present in *Verbascum* species should be identified and that their potential as alternative natural fungicides in biological control should be further supported by advanced research.

Key Words: *Antifungal activity, Rhizoctonia solani, Verbascum spp., Methanol extract, Natural fungicide.*

Farklı Bölgelerden Toplanan *Verbascum* L. (Sığırkuyruğu) Türlerinden Elde Edilen Metanol Ekstraktlarının *Rhizoctonia solani*'ye Karşı Antifungal Aktivitesi

Özet

Bitkiler, bitki patojenleriyle mücadelede sekonder bileşikler içermeleri nedeniyle tercih edilen önemli doğal kaynaklar arasında yer almaktadır. Bu çalışmada, ekolojik olarak farklı lokasyonlardan (Karasu, Konya, Bolu, Arifiye ve Manisa) toplanan bölgesel *Verbascum* (Sığırkuyruğu) türlerine ait metanol ekstraktlarının, toprak kökenli, geniş konukçu aralığına sahip fitopatojen bir fungus olan *Rhizoctonia solani* (J.G. Kühn) üzerindeki antifungal etkileri *in vitro* koşullarda araştırılmıştır. Bunun için *Verbascum* türlerinin çiçek ve yaprak kısımlarından metanol ekstraktları elde edilmiş ve bu ekstraktların farklı konsantrasyonlarının (%0,5, %1, %2 ve %4) besi ortamında miselyal gelişimi inhibe etme potansiyeli değerlendirilmiştir. Test edilen tüm ekstraktlar belirli düzeylerde antifungal aktivite göstermiştir. Miselyal gelişimi en fazla baskılayan ekstrakt, Konya'dan toplanan örneklerden hazırlanmış olup, bu ekstrakt miselyal gelişimi %55 oranında engellenmiştir. Bunu %45 inhibisyon oranı ile Karasu ekstraktı takip etmiştir. Diğer lokasyonlardan elde edilen ekstraktlar ise değişen oranlarda antifungal aktivite sergilemiş ve miselyal gelişimi %7,5 ile %36,25 arasında inhibe etmiştir. Elde edilen bulgular, *Verbascum* türlerinden elde edilen metanol ekstraktlarının *Rhizoctonia solani*'ye karşı antifungal aktivite gösterdiğini ve bu etkinin uygulanan doz miktarına bağlı olarak arttığını ortaya koymaktadır. Bu sonuçlar, *Verbascum* türlerinin içerdiği aktif bileşiklerin belirlenmesi ve biyolojik mücadelede alternatif doğal fungisitler olarak kullanım potansiyellerinin ileri araştırmalarla desteklenmesi gerektiğini göstermektedir.

Anahtar Kelimeler: *Antifungal aktivite, Rhizoctonia solani, Verbascum spp., Metanol ekstraktı, Doğal fungisit.*

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Negative Effects of Biopesticides on Bees

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Abstract

Biopesticides are compounds derived from natural sources such as plants, bacteria, and minerals, serving as environmentally friendly alternatives to synthetic pesticides. They are generally preferred due to their lower toxicity and specificity towards target organisms. However, their impact on non-target species, particularly bees, which play a crucial role in ecosystem sustainability and agricultural production, must be carefully evaluated. Bees contribute significantly to biodiversity conservation and agricultural productivity through pollination. This study examines the potential risks and benefits of biopesticides on bee populations. Research indicates that although biopesticides tend to be less toxic than synthetic pesticides, their effects on bees vary depending on the active ingredient, formulation, and level of exposure. For instance, microbial biopesticides such as Bacillus thuringiensis (Bt) are considered to pose minimal risk to bees. In contrast, plant-based compounds such as neem oil and pyrethrins have been observed to negatively affect bee foraging behavior and reproduction. Additionally, interactions between biopesticides and other environmental stressors, such as pathogens and nutritional deficiencies, may exacerbate their adverse effects on bee health. Despite these concerns, biopesticides offer advantages, including biodegradability and lower environmental persistence, reducing unintended impacts on beneficial insects. When integrated pest management (IPM) strategies are applied effectively, the risks to pollinators can be minimized while maintaining agricultural productivity. Therefore, further research is needed to understand the long-term effects of biopesticides on bee populations and to develop safe application guidelines. A balanced approach is essential to ensure both agricultural productivity and pollinator conservation, supporting ecological and agricultural sustainability.

Key Words: *Bee health, Biopesticide, Ecological balance, Integrated pest management (IPM), Agricultural sustainability*

1. Introduction

Pollinators, particularly honeybees (*Apis mellifera*), play a vital role in maintaining biodiversity and ensuring food security through the pollination of agricultural crops and wild plants (Khalifa et al., 2021; Requier et al., 2023). However, in recent decades, significant declines in bee populations have raised global concern, prompting extensive research into the multifactorial causes of these losses (Lima et al., 2022). Among the various anthropogenic stressors, the use of pesticides in modern agriculture has been widely implicated in the deterioration of bee health (Zhao et al., 2022) . While conventional synthetic pesticides are known for their acute and chronic toxicity to pollinators, biopesticides—marketed as safer, eco-friendly alternatives—have increasingly gained attention as part of integrated pest management (IPM) strategies (Cappa et al., 2022; Demirözer et al., 2022) .

Biopesticides, which are derived from natural organisms such as bacteria, fungi, viruses, or plant extracts, are generally assumed to be less harmful to non-target organisms, including pollinators (Cappa et al., 2022; Guedes et al., 2024). This perception has led to their widespread acceptance and use without sufficient evaluation of their sublethal or chronic impacts on beneficial insects. Recent studies, however, have begun to challenge this assumption, highlighting that certain biopesticides may impair critical physiological and behavioral functions in bees, such as foraging efficiency, learning and memory, immune response, and colony development (Carlesso et al., 2020; Almeida et al., 2022). Moreover, the synergistic effects of biopesticides when combined with other environmental stressors, such as nutritional deficiencies, pathogens, or climate change, remain poorly understood. Given the essential ecological role of bees and the growing reliance on biopesticides in sustainable agriculture, it is crucial to reassess the environmental safety profiles of these products. This study aims to investigate the potential adverse effects of commonly used biopesticides on honeybee health, with a particular focus on sublethal behavioral and physiological impacts. By doing so, it seeks to contribute to a more nuanced understanding of how "green" plant protection strategies may still pose risks to vital pollinator species.

2. Biopesticides Effects on Bee

Biopesticides are derived from natural organisms such as bacteria, fungi, viruses, or plant extracts.

2.1. Entomopathogenic bacteria

The most studied entomopathogenic bacteria include species from the genera Bacillus, Beauveria, and Metarhizium. Among these, *Bacillus thuringiensis* (Bt) is perhaps the most widely recognized for its use in pest control. These bacteria produce toxins that can damage the insect's gut, leading to death. While these bacteria are often lethal to pests, their effects on non-target organisms like bees are not always well understood (Rousset and Gallet, 2025). Entomopathogenic bacteria, particularly strains of *B. thuringiensis*, have been shown to be toxic to bees under certain conditions. While bees are not the intended targets of these bacteria, they may encounter them when foraging on contaminated plants or surfaces. Bees can ingest or come into contact with bacterial spores or toxins, which can potentially disrupt their digestive systems, impair their health, or even result in death. However, some strains of Bacillus may have minimal or no direct lethal effects on bees, depending on the concentration and strain involved (Mommaaerts et al., 2010; Alkassab et al., 2022). Exposure to entomopathogenic bacteria could also suppress the bee's immune system (Steinigeweg et al., 2021). Bees rely heavily on their immune response to fend off pathogens, parasites, and other environmental stressors. If bees are infected by harmful bacteria, their immune system might be compromised, leaving them more susceptible to other diseases or pathogens, such as Nosema or the varroa mite (Alquisira-Ramírez et al., 2017). A weakened immune system can lead to colony collapse, affecting not only individual bees but also the entire hive. Sublethal exposure to entomopathogenic bacteria might not kill bees immediately but can cause behavioral changes. Affected bees may become less efficient in foraging, decrease in grooming or nursing activities, or exhibit altered communication such as waggle dancing (Malone et al., 2001; Mommaerts et al., 2010). These behavioral shifts could affect the overall productivity of the colony, impairing pollination efforts and leading to decreased honey production. The widespread use of entomopathogenic bacteria in agriculture or horticulture may pose a risk to bees if these bacteria are applied to crops that bees frequent. Pesticide treatments containing entomopathogenic bacteria could persist in the environment, and bees could be exposed to these pathogens during their foraging activities. The long-term ecological impact of such exposure is not fully understood but could have cumulative effects on bee populations over time. While there are concerns about the harmful effects, some studies suggest that entomopathogenic bacteria may have potential benefits for bee health under certain conditions. For example, Bacillus species have been found to outcompete or inhibit the growth of harmful pathogens that affect bees, like *Nosema apis* (a protozoan that causes Nosema disease). In this sense, entomopathogenic bacteria could serve as a form of natural biological control to support colony health, though careful management would be necessary to avoid inadvertent harm.

2.2. Entomopathogenic Fungi

Entomopathogenic fungi, such as Beauveria bassiana and Metarhizium anisopliae, are increasingly utilized in integrated pest management due to their specificity and environmental safety; however, their non-target effects on pollinators warrant careful evaluation. Although adult bees generally exhibit low susceptibility to infection under field-relevant concentrations, sublethal impacts—including behavioral alterations, reduced foraging efficiency, and impaired learning—have been documented following exposure to certain fungal strains (Almeida et al., 2022; Leite et al., 2022; Bava et al., 2022). Moreover, the larval stages may be more vulnerable, especially when spores are introduced into the hive environment (Omuse et al., 2022). These effects, while often subtle at the individual level, could potentially accumulate to impair colony-level function, particularly when compounded by additional stressors such as pesticide exposure or nutritional deficiencies. Therefore, risk assessments of entomopathogenic fungi should consider strain-specific virulence, exposure routes, and the health status of bee populations to ensure pollinator safety in biological control programs.

2.3. Entomopathogenic Nematodes

Entomopathogenic nematodes (EPNs), primarily from the genera Steinernema and Heterorhabditis, are widely used as biological control agents due to their ability to parasitize and kill a broad range of insect pests. These nematodes harbor symbiotic bacteria (e.g., *Xenorhabdus spp*. and *Photorhabdus spp*.) that contribute to the host's death by releasing toxins. Although EPNs are generally considered safe for non-target organisms, including pollinators, the potential effects on bees have become an emerging area of concern (Erler et al., 2022). Bees, particularly *Apis mellifera* and other eusocial species, are not typical hosts for EPNs due to their mobility, grooming behavior, and relatively dry external cuticle, which collectively reduce the likelihood of successful infection. However, under laboratory conditions or when EPNs are applied in high concentrations and in moist environments—such as hive interiors or floral resources—there is evidence of possible adverse interactions. Some studies have shown that EPNs can cause high mortality (Dutka et al., 2015). Despite these risks, most field applications of EPNs appear to pose minimal direct threat to bee populations. Their survival and infectivity are limited on dry surfaces like flowers, and they are not typically attracted to or capable of breaching the protective defenses of adult bees. Nevertheless, comprehensive risk assessments are essential, particularly for stingless bees or solitary bee species that nest in soil or decaying wood, where EPNs are more likely to persist and interact with developing brood.

2.4. Viruses

Honey bees are known to host more than 20 distinct viruses, which typically remain latent and asymptomatic unless activated by external stressors (McMenamin and Genersch, 2015). When such stressors compromise the bees' immune function, viral replication can increase, and elevated viral loads have been associated with colony collapse (McMenamin and Genersch, 2015). Although RNA viruses from the families Dicistroviridae and Iridoviridae are frequently detected in collapsing colonies and have been proposed as potential biopesticides (Bromenshenk et al., 2010; McMenamin and Genersch, 2015), there remains a significant paucity of targeted studies investigating their direct effects on honey bees. In contrast, studies examining the impacts of nuclear polyhedrosis viruses (NPVs), granulosis viruses, and entomopoxviruses—originally isolated from other insect species—have reported no adverse effects on honey bees, thereby suggesting host specificity and indicating their relative safety in microbial pest management programs (Alves et al., 1996). With respect to the potential impacts of viral biocontrol agents on bumble bees, the body of research remains limited. Nevertheless, existing studies suggest that granuloviruses isolated from *Cydia pomonella* do not negatively affect *Bombus terrestris* worker survival, foraging behavior, or overall colony fitness (Mommaerts et al., 2009).

2.5. Plant Extracts

The use of plant-based biopesticides has emerged as a sustainable alternative to synthetic chemical pesticides, offering potential advantages such as biodegradability, target specificity, and lower toxicity to non-target organisms (Haritha et al., 2021). However, growing evidence indicates that certain plant extracts employed as biopesticides may pose unforeseen risks to pollinators, particularly bees, which are essential for ecosystem functioning and agricultural productivity. Despite being considered environmentally friendly, the phytochemical constituents in some biopesticides can exert sublethal or even lethal effects on various species of bees, including honeybees (*Apis mellifera*), bumblebees (*Bombus spp*.), and solitary bees (Morandin et al., 2015; Tome et al., 2015).

Plant-derived compounds such as essential oils, alkaloids, saponins, and phenolics are designed to deter or kill insect pests, but these bioactive substances can also affect the physiology and behavior of bees (Demirözer et al., 2022). For example, neem-based biopesticides containing azadirachtin have demonstrated antifeedant and growth-regulating effects in target pests, yet studies have shown that exposure to sublethal doses can impair bee foraging efficiency, navigation, and learning capacity (Bernardes et al., 2017; Barbosa et al., 2015; Gomes et al., 2020). Similarly, essential oils such as thymol and eugenol may disrupt neural signaling pathways in bees, potentially altering their olfactory perception and communication.

Sublethal exposure to these compounds may also compromise bees' immune responses, making them more susceptible to pathogens such as *Nosema spp*. and viruses (Chaimanee et al., 2021). Additionally, repeated exposure to plant biopesticides through contaminated nectar, pollen, or water sources can result in cumulative toxicity, especially during peak foraging seasons. Larval development may also be disrupted when brood food is contaminated, affecting colony health and productivity over the long term.

3. Conclusion

The reviewed literature underscores the complexity of biopesticide interactions with honeybee health, challenging the common assumption that these products are inherently safe for pollinators. While biopesticides—including entomopathogenic bacteria, fungi, nematodes, viruses, and plant extracts—are widely promoted as eco-friendly alternatives to synthetic pesticides, mounting evidence reveals that some of these agents can have unintended sublethal or chronic effects on bees. These effects range from impaired foraging behavior, learning deficits, and immune suppression to increased vulnerability to pathogens and potential colony-level impacts. Such outcomes are particularly concerning given the central role of honeybees in pollination services and ecosystem stability.

Among the biopesticide groups, Bacillus thuringiensis and other entomopathogenic bacteria can interfere with bee gut health and immunity; certain fungal strains, though generally low in direct virulence, may subtly impair behavior and larval development; entomopathogenic nematodes, while less likely to infect bees directly, pose possible risks under moist conditions or in species nesting in exposed habitats; and plant-based biopesticides, despite their natural origin, can contain bioactive compounds that disrupt key physiological and neurological functions in bees. Viral agents, although largely species-specific, remain under-studied in terms of their long-term ecological impacts, particularly in diverse bee communities.

4. Future Directions

Comprehensive Risk Assessments: Future studies must include standardized, long-term risk assessments of biopesticides under realistic field conditions. These assessments should consider species-specific sensitivities, life stages (e.g., larvae vs. adults), and exposure routes (e.g., contaminated pollen, nectar, or water).

Sublethal and Synergistic Effects: Greater emphasis should be placed on investigating sublethal effects and the potential for synergistic interactions between biopesticides and other stressors, such as poor nutrition, climate change, or existing pathogen loads.

Diversity of Bee Species: Most current research focuses on *Apis mellifera*; however, *non-Apis* pollinators such as bumblebees and solitary bees may exhibit different susceptibilities. Expanding studies to include a broader range of species is critical for biodiversity conservation.

Biopesticide Formulation Improvements: There is a need for the development of safer biopesticide formulations that minimize non-target effects on bees, including innovations in application timing, dosage, and delivery methods that reduce pollinator exposure.

Policy and Regulatory Updates: Regulatory frameworks should be updated to reflect new scientific insights into biopesticide toxicity. This includes integrating pollinator health benchmarks into the approval process for biopesticide products.

Integrated Pest and Pollinator Management (IPPM): Holistic strategies that align pest control goals with pollinator protection—such as using ecological intensification, crop diversification, and habitat conservation—should be promoted.

By pursuing these directions, researchers, regulators, and agricultural stakeholders can more effectively balance pest control needs with the imperative to protect pollinators, thereby advancing sustainable and resilient agroecosystems.

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ID: 580

Immobilizing Pb in soil polluted with Pb batteries effluents: Confirmation at biological and chemical scales

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Abstract

Untreated effluents from Pb battery repair workshops pollute the soil when released. Resultantly, higher concentrations of Pb in the surrounding soils are observed in several areas of Punjab, Pakistan. Fortunately, cement containing phosphate (PC) can efficiently immobilize Pb in soil and reduce ecological and human health issues linked with Pb. In this experiment, we collected Pb battery polluted soil having Pb concentrations of 711 mg kg^{-1} and amended with six doses of PC, i.e. 0, 0.5, 1, 1.5, 2, and 2.5% of soil. The soil was initially incubated for 50 days and later used for plant experiment, earthworm incubation, and chemical scales for a further 50 days. Pb fixation in soil was measured by different scales, i.e., chemical scales [$Ca(NO_3)_2$ and diffusive gradient in thin films (DGT)] and biological scales (lettuce plants and earthworms). After the experiment, concentrations of Pb in lettuce roots and shoots and earthworms decreased with increasing PC dose to 2%, while no significant changes were observed for 2 and 2.5% doses. Biomass of both biological entities also followed identical patterns. Moreover, bioavailable Pb in the soil after the experiment, as assessed by $Ca(NO_3)_2$ and DGT, significantly decreased by raising the PC dose to 2%, and there was no change thereafter. Correlations between Pb concentrations in biological entities and chemical scales were > 0.96, depicting the efficacy of PC for remediating Pb-polluted soils. Phosphate in PC reacted with Pb to form a stable Pb-phosphate compound, leading to Pb fixation in soil. A 2% PC dose was more efficient and economical than 2.5% for ecological restoration.

Key Words: *Effluents, Workshops, Cement, Biomass, Correlation, Efficient*

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Effect of Genotype and Sex on Slaughter and Carcass Characteristics in Quail

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Abstract

This study was carried out to determine the effect of sex and genotype on slaughter and carcass characteristics of 4 different quail genotypes (Cyprus black, Texas white, Italian yellow, Pharaoh (wild type)). The animal material of the study consisted of a total of 40 quails, 5 females and 5 males from 4 genotypes at the age of 5 months. Quails were randomly selected from an actively mating and laying flock. Slaughtering was done individually and carcass weight, edible viscera weights and intestine lengths were measured in all quails. Testicular weight was measured in male quails and oviduct length was measured in females. After slaughter, the hot carcass was cooled for 12 hours and cold carcass weight and cold carcass ratio were calculated. In the study, live weight of female and male sex groups were 295.71 and 244.72 g, respectively ($p<0.001$). When genotypes were evaluated in terms of live weight, Pharaoh, Italian yellow, Cyprus black and Texas white genotypes were determined as 278.88, 249.51, 239.21 and 313.25, respectively ($p<0.001$). In terms of hot carcass, the yields of genotypes were 164.76, 167.41, 158.65 and 215.48, respectively ($p<0.001$). Carcass yield, which is an important yield characteristic, was calculated as 60.17, 67.34, 66.53 and 69.17% in the same order for genotype groups ($p<0.001$). When evaluated in terms of sex groups, it was calculated as 60.82% and 70.79% in female and male sex groups ($p<0.001$). When the groups were evaluated in terms of cold carcass ratio, 62.73% and 73.68% were determined as 62.92%, 69.38%, 69.03% and 71.48% in gender groups, respectively ($p<0.001$). In the study, part weights were also calculated and the yields of the genotype groups in terms of thighs were 39.59, 39.06, 37.90 and 53.07 g, respectively ($p<0.001$). In terms of whole wing weight, the yields of genotype groups were 12.52, 12.80, 12.73 and 16.47 g, respectively ($p<0.001$). When we evaluated the sex and genotype groups in terms of thigh carcass ratio and wing carcass ratio, no difference was found ($p>0.05$). Breast weights of genotypes were 64.40, 69.93, 64.70 and 90.14 g and boneless breast weights were 51.94, 56.31, 52.74 and 73.40, respectively ($p<0.001$).When we looked at the breast carcass ratios of genotypes, the averages were 37.48, 40.33, 39.31 and 40.44%, respectively ($p<0.001$). When we looked at the breast carcass ratios of the sex groups, it was determined as 40.63% and 38.15%, respectively ($p<0.05$). According to gender groups, liver weights were 8.48 and 4.44, respectively ($p<0.001$). The liver carcass ratios of the genotypes were 1.19%, 1.30, 1.18 and 1.00, respectively ($p<0.05$). When an evaluation was made in terms of gizzard weight, the genotype yields were 4.67, 4.00, 3.67 and 5.06, respectively ($p<0.001$). There was no difference between the sex groups in terms of heart weight, while heart carcass ratios were 1.24% and 1.10%, respectively. When evaluated in terms of gut length trait, genotype yields were 79.45, 82.40, 76.30 and 95.75 and sex groups were 91.88 and 75.08 cm, respectively ($p<0.001$). When the genotype groups were evaluated in terms of testis carcass ratio, it was determined as 3.57, 3.67, 3.71 and 3.72% ($p<0.001$).When the results of the research are considered, if a breeding for meat production is to be done, it is more appropriate to use the males of the Texas white genotype due to its advantage in both live weight, carcass yield and piece and edible internal organ weights. When we look at the characteristics of the carcass, it was seen that the breast constituted a large part of the carcass and this ratio was the lowest in the pharaoh quails.

Key Words: *Quail, Slaughter, Carcass, Genotype, Sex*

Bıldırcınlarda Genotipin ve Cinsiyetin Kesim ve Karkas Özelliklerine Etkisi

Özet

Bu çalışma 4 farklı bıldırcın genotipinde (Kıbrıs karası, Teksas beyazı, İtalyan sarısı, Firavun(yabani tip)) kesim ve karkas özelliklerine cinsiyet ve genotipin etkisini belirlemek amacıyla yürütülmüştür. Çalışmanın hayvan materyalini 5 aylık yaştaki 4 genotipten 5 dişi 5 erkek olmak üzere toplamda 40 adet bıldırcın oluşturmuştur. Bıldırcınlar aktif olarak çiftleşen ve yumurtlayan bir sürüden rastgele seçilmiştir. Kesimler bireysel olarak yapılmış olup bütün bıldırcınlarda karkas ağırlığı, yenilebilir iç organ ağırlıkları, bağırsak uzunlukarı ölçülmüştür. Erkek bıldırcınlarda testis ağırlığı, dişilerde ise yumurta kanalı uzunluğu ölçümleri yapılmıştır. Kesimin ardından sıcak karkas 12 saat dinlendirilerek soğutulmuş ve soğuk karkas ağırlığı ve soğuk karkas oranı hesaplanmıştır. Çalışmada dişi ve erkek cinsiyet gruplarında canlı ağırlık sırasıyla 295.71 ve 244.72 g olarak belirlenmiştir ($p<0.001$). Canlı ağırlık bakımından genotipler değerlendirildiğinde Firavun, İtalyan Sarısı, Kıbrıs karası ve Teksas beyazı genotipleri sırasıyla 278.88, 249.51, 239.21 ve 313.25 olarak belirlenmiştir ($p<0.001$). Sıcak karkas bakımından genotiplerin verimlerine bakıldığında aynı sırayla 164.76, 167.41, 158.65 ve 215.48 olarak bulunmuştur ($p<0.001$). Önemli bir verim özelliği olan karkas randımanı genotip grupları bakımından aynı sırayla %60.17, 67.34, 66.53 ve 69.17 olarak hesaplanmıştır ($p<0.001$). Cinsiyet grupları bakımından değerlendirildiğinde ise dişi ve erkek cinsiyet gruplarında %60.82 ve 70.79 olarak hesaplanmıştır ($p<0.001$). Gruplar soğuk karkas oranı bakımından değerlendirildiğinde cinsiyet gruplarında sırayla %62.73 ve 73.68 genotip grupları bakımından değerlendirildiğinde ise aynı sırayla %62.92, 69.38, 69.03 ve 71.48 olarak tespit edilmiştir ($p<0.001$). Çalışmada parça ağırlıklarıda hesaplanmış olup kalçalı but bakımından genotip gruplarının verimleri sırayla 39.59, 39.06, 37.90 ve 53.07 g olarak tespit edilmiştir ($p<0.001$). Bütün kanat ağırlığına baktığımızda genotip gruplarının verimleri sırayla 12.52, 12.80, 12.73 ve 16.47 g olarak tespit edilmiştir ($p<0.001$). Cinsiyet ve genotip gruplarını but karkas oranı ve kanat karkas oranı bakımından değerlendirdiğimizde herhangi bir farklılık tespit edilmemiştir ($p>0.05$). Genotiplerin göğüs ağırlıkları 64.40, 69.93, 64.70 ve 90.14 g kemiksiz göğüs ağırlıkları ise sırasıyla 51.94, 56.31, 52.74 ve 73.40 olarak ölçülmüştür ($p<0.001$).Genotiplerin göğüs karkas oranlarına baktığımızda ortalamalar aynı sırayla %37.48, 40.33, 39.31 ve 40.44 olarak tespit edilmiştir ($p<0.001$). Cinsiyet gruplarının göğüs oranlarına baktığımızda sırayla % 40.63 ve 38.15 olarak tespit edilmiştir ($p<0.05$). Cinsiyet gruplarına göre ciğer ağırlıkları sırayla 8.48 ve 4.44' dür ($p<0.001$). Genotiplerin ciğer karkas oranlarına baktığımızda sırayla %1.19, 1.30, 1.18 ve 1.00 olarak tespit edilmiştir ($p<0.05$).Taşlık ağırlığı bakımından bir değerlendirme yapıldığında genotip verimleri sırasıyla 4.67, 4.00, 3.67 ve 5.06' dır ($p<0.001$). Cinsiyet gruplarında kalp ağırlığı bakımından herhangi bir farklılık tespit edilemezken kalp karkas oranları sırasıyla %1.24 ve 1.10 olarak tespit edilmiştir. Bağırsak uzunluğu özelliği bakımından değerlendirildiğinde genotip verimleri sırasıyla 79.45, 82.40, 76.30 ve 95.75 cinsiyet grupları ise 91.88 ve 75.08 cm olarak tespit edilmiştir($p<0.001$). Genotip grupları testis karkas oarnı bakımından değerlendirilmesinde ise %3.57, 3.67, 3.71 ve 3.72 olarak tespit eilmiştir ($p<0.001$).Araştırma sonuçlarına bakıldığında et üretim amaçlı bir yetiştiricilik yapılacaksa hem canlı ağırlık hem karkas randımanı hemde parça ve yenilebilir iç organ ağırlıklarındaki avantajı dolayısıyla teksas beyazı genotipinin erkeklerinin kullanılması daha uygundur. Karka özelliklerine baktığımızda karkasın büyük bir kısmını göğüsün oluşturduğunu, bu oranında en düşük firavun bıldırcınlarında olduğu görülmüştür.

Anahtar Kelimeler: *Bıldırcın, kesim, karkas, genotip, cinsiyet*

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Selection of Stable and High-Yielding Short-Duration Inbred Rice (*Oryza sativa* L.) Genotypes for the Boro Season in Bangladesh Using WAASB and MTSI Indices

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Abstract
Rice (*Oryza sativa* L.) is the staple food of Bangladesh, with its production tripling since independence. However, declining cultivable land and climate change, particularly erratic rainfall, have led to prolonged water scarcity during the Boro season. To ensure future rice security, genetic improvements for short-duration, high-yielding varieties are essential. In response, the Bangladesh Rice Research Institute (BRRI) developed genotypes with a life cycle of ≤145 days, requiring less water while maintaining productivity. This study evaluated four advanced fixed lines (V1 = BR11318-5R-63, V2 = BR11337-5R-72, V3 = SVIN109, V4 = IR17A1723) alongside two reference varieties (V5 = BRRI dhan81, V6 = BRRI dhan96) across 11 locations in Bangladesh during the 2022–23 Boro season. Combined ANOVA revealed significant genotype, environment, and genotype-environment interaction (GEI) effects ($p \leq 0.001$) on yield and related traits. Broad-sense heritability (h^2b) ranged from 0.05 to 0.50, with most traits showing high selection accuracy (>0.80). Stability analysis using weighted average of absolute scores biplots (WAASB) identified V1 and V3 as the most stable, while GGE biplots highlighted V2's superior grain yield (GY) in multiple locations. Multi-trait stability index (MTSI) ranked V2 as the most stable based on GY and seven yield-contributing traits. Factor analysis further confirmed its agronomic superiority, with GD and TGW showing the highest broad-sense heritability (0.92), followed by PHT (0.885) and GY (0.833), with selection gains ranging from 1.48% to 9.54%. Overall, BR11337-5R-72 (V2) emerged as the most promising short-duration, high-yielding, and stable genotype for Boro rice cultivation, requiring further evaluation and promotion for large-scale adoption.
Key words: *BRRI; Rice; Yield; stability; GEI.*

1. Introduction

Rice (*Oryza sativa* L.) holds a predominant position as the primary grain crop in Bangladesh's agricultural sector. Given the dietary patterns, ensuring "rice security" plays a pivotal role in achieving food security, a situation mirrored in numerous other nations (Brolley, 2015). Rice production has increased by three times since the liberation of Bangladesh and reaching about 39.1 MT in 2023 (Kabir et al., 2020) and hold third-largest producer of rice globally (Sun et al., 2023). However, future projections indicate a rising demand for rice due to population growth. (Kabir et al., 2015) estimated that approximately 44.6 million metric tons of rice will be needed by 2050. On the other hand, the cultivable land area will be 11.07 M ha in 2050 compared to 12.10 M ha in 2020 (Kabir et al., 2020). Additionally, the country is grappling with the impacts of climate change, including erratic rainfall

patterns and prolonged droughts. Therefore, enhancing the genetic potential of rice crops to increase yield remains crucial for meeting the future rice demand in Bangladesh.

Bangladesh experiences distinct wet and dry seasons, with the dry season, known as the boro season, posing a challenge for rice cultivation due to water scarcity. Therefore, the resilience of short-duration boro rice (BR-SD) varieties becomes particularly valuable. According to research by Rabbi et al. (Rabbi et al., 2020), rice varieties in Bangladesh are classified based on their ecological adaptation and product requirements to better understand the changing potential yield over time. Favorable boro rice (FBR) varieties are categorized as short duration (SD), cultivated during the boro season in favorable environments with minimal abiotic stresses apart from natural disasters. The SD varieties typically have a lifespan of up to 145 days. Conversely, long-duration boro rice types include cultivars grown in similarly favorable environments but with a lifespan exceeding 145 days. FBR-SD varieties have proven to be well-suited for the conditions, requiring less water and completing their life cycle within the limited duration of the dry season. It's important to note that the Bangladesh Rice Research Institute (BRRI) is the leading institution for rice research in the country, having released 108 inbred and 08 hybrid rice varieties. Additionally, the Adaptive Research Division (ARD) of BRRI is tasked with conducting validation and adaptation trials across various agro-ecological zones (AEZs) to identify stable cultivars for release in Bangladesh. While scientists are actively working on genetically enhancing crops by selectively incorporating elite alleles and traits into desired genetic backgrounds, conducting multi-environment trials (METs) is a crucial step in breeding programs before releasing varieties to farmers. Selecting superior genotypes based on yield across diverse AEZs can be highly effective, given that yield is a complex quantitative trait heavily influenced by environmental variations. However, choosing the best genotype from a genetic pool based on their observable traits presents a significant challenge (Alam, 2019; Alam, Akter, Khan, Alam, et al., 2023; Alam, Akter, Khan, Amin, et al., 2024). In the pursuit of stable genotypes, the additive main effects and multiplicative interaction (AMMI) model plays a pivotal role. Moreover, a novel index called weighted average absolute scores (WAAS), derived from the AMMI model, is integrated into METs analysis indices (Alam, Akter, Khan, Alam, et al., 2024). Alongside AMMI, the genotype-genotype environment (GGE) biplot graphical model is commonly utilized to identify environments and winning genotypes within those environments (Akter et al., 2015). The GGE biplot method is also employed to pinpoint stable genotypes and evaluate their interaction with yield and environments. On the flip side, linear mixed models (LMMs) are commonly utilized to improve selection efficiency in various studies (Ahsan et al., 2024; Alam, Akter, Khan, Alam, et al., 2024; Alam, Akter, Khan, Amin, et al., 2024; Alam, Akter, Khan, Rashid, et al., 2023; Khan et al., 2024; Olivoto & Nardino, 2021; Pimentel et al., 2014; Schmidt et al., 2019). Yet, comprehending the genetic mechanisms dictating trait inheritance and the impact of genetic elements on their manifestation is crucial for the triumph of a breeding program (Fotirić-Akšić et al., 2011). An efficient method for analyzing and estimating genetic parameters using agronomic traits is through the restricted maximum likelihood (REML) model (Marchi et al., 2019). This method has been employed across diverse crop breeding endeavors, such as sweet potato (Alam, Akter, Khan, Alam, et al., 2024), white Guinea yam (Norman et al., 2022), soybean (Follmann et al., 2019), and others. An exposition by Olivoto et al. (Olivoto et al., 2019) delves into the theoretical foundations of the Multi-Trait Stability Index (MTSI), facilitating the selection of superior genotypes in METs based on high yield and stability, while considering multiple traits.

Introducing advanced breeding methods and employing METs in conjunction with modern stability analysis models like AMMI, GGE biplot, and MTSI in Bangladesh's rice farming can facilitate the discovery and choice of resilient genotypes with strong yield capabilities. This approach will aid in addressing the growing need for rice production amid environmental constraints and shrinking arable land. The present study was undertaken to examine the four advanced lines with two released varieties from BRRI at diverse environment to check the stability and yield advantages of advanced lines compared to released varieties.

2. Materials and methods

2.1. Description of the study area

The study was conducted over the 2022-23 growing season across 11 districts in Bangladesh: Rangpur, Gopalganj, Faridpur, Barishal, Natore, Sirajganj, Feni, Kushtia, Habiganj, Manikganj, and Gazipur, as illustrated in Figure 1. The experimental fields were chosen in collaboration with the Department of Agriculture Extension (DAE), taking into account variations in soil texture (BRRI, 2024) and elevation, which are detailed in Table 1. Additionally, monthly data on maximum and minimum temperatures, and relative humidity were collected from November to May 2022-23 at the research sites, covering the Boro growing season (BMD, 2023) (Figure 2).

2.2 Plant materials

This research included four advanced lines of FBR-SD: BR11318-5R-63, BR11337-5R-72, SVIN109, and IR17A1723. Two varieties released by BRRI were also included as checks to compare their yield and related characteristics. One check was BRRI dhan81, with the pedigree BR7358-5-3-2-1-HR2. The other check, BRRI dhan96, has the pedigree BR(Bio) 9787-BC2-63-2-2. All six genotypes exhibited uniform flowering, grain maturity, and good wrapping quality with culms. The flag leaves of the studied rice genotypes were erect. Detailed information about these six rice genotypes is presented in Table 2, while a visual representation of the raw rice grain is depicted in Figure 3.

Table 1. Description of the eleven selected locations during the Boro 2022-23 season

Location	Agro-ecological representation	Latitude	Longitude	Elevation	Soil texture
Rangpur	AEZ3	25°44'17"N	89°17'01"E	34	Loam- clay loam
Gopalganj	AEZ14	23°01'78"N	89°81'05"E	3.1	Clay loam-sandy loam
Faridpur	AEZ12	23°25'10"N	89°53'56"E	11	Clay loam-sandy loam
Barishal	AEZ13	22°42'35"N	90°20'00"E	2	Silty clay- clay
Natore	AEZ11	22°36'22"N	89°22'19"E	17	Clay loam
Sirajganj	AEZ4	24°39'34"N	89°65'72"E	13	Clay to loamy
Sonagazi	AEZ23	22°81'28"N	91°38'89"E	5	Clay
Kushtia	AEZ10	23°88'36"N	89°13'28"E	27	Clay-loam
Habiganj	AEZ19	24°31'05"N	91°21'46"E	6	Clay to loamy
Manikganj	AEZ8	23°86'56"N	90°00'98"E	15.92	Loamy/Clay
Gazipur	AEZ28	23°59'26"N	90°24'09"E	34	Silty clay loam

Table 2. The detailed information of FBR-SD genotypes

Genotype code	Genotypes	Year of release	Grain type
V1	BR11318-5R-63	NR	Medium slender
V2	BR11337-5R-72	NR	Medium slender
V3	SVIN109	NR	Medium slender
V4	IR17A1723	NR	Medium slender
V5^{CK}	BRRI dhan81	2017	Medium slender
V6^{CK}	BRRI dhan96	2020	Medium bold

^{NR} Not released yet

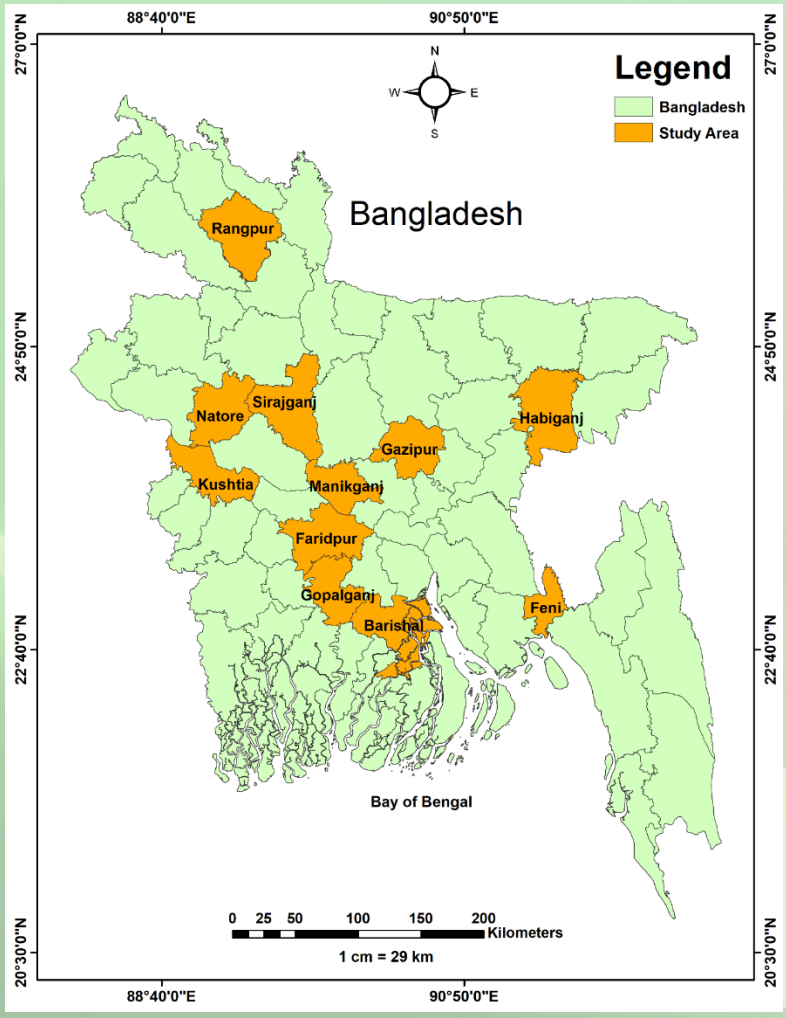


Figure 1. Locations of the study area in different districts in Bangladesh.

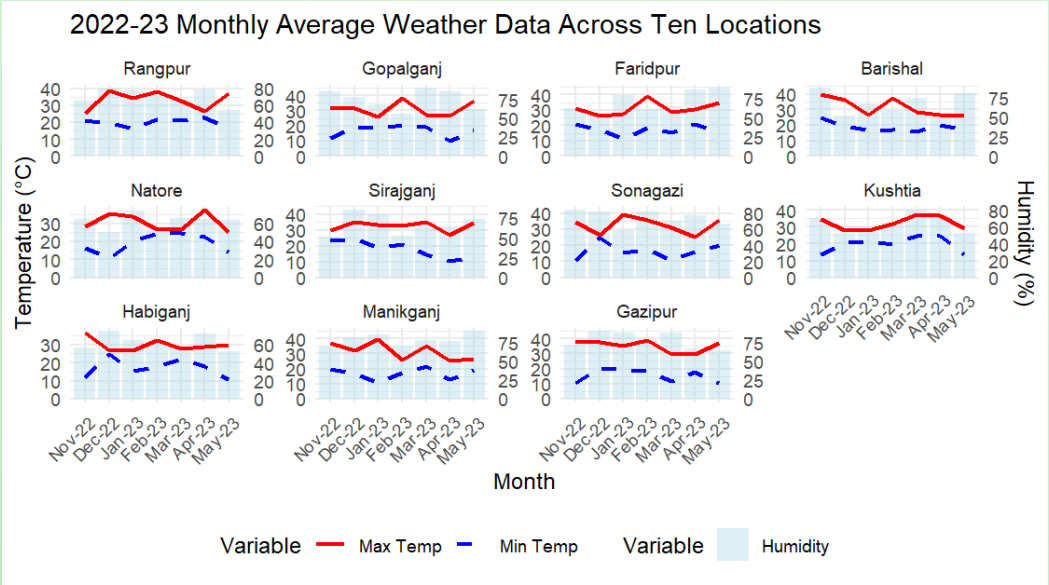


Figure 2. Monthly mean Maximum Temperature (°C), Minimum Temperature (°C) & Relative Humidity (%) of selected eleven (11) experiment locations in Bangladesh during 2022-23 Boro season.



Figure 3. A pictorial view of raw grain for the six FBR-SD genotypes. [CK] check

2.3 Experimental design

In every location, the entire experimental field was partitioned into three blocks, each comprising six plots, making a total of eighteen plots. These trials were replicated three times in each location, adhering to a randomized complete block design (RCBD). Each plot had a size of 20 m^2 (measuring 4.0 m by 5.0 m). Seedlings aged between 35 to 40 days were transplanted with a spacing of 20 cm by 20 cm.

2.4 Crop husbandry

The research site was plowed until achieving a finely textured seedbed for seedbed preparation. Seeding occurred between the last week of November and the last week of December 2022 across eleven locations. Fertilizers were applied at a ratio of 260:100:120:110:10 kg/ha of Urea:DAP:MoP:Gypsum:ZnSO4, respectively (Ahmmed et al., 2018). All fertilizers except urea were applied as basal, while urea was split into three equal portions applied at 10 days, 30 days after transplanting, and 5 days before the panicle initiation stage. Weeding and irrigation followed BRRI's recommended management practices as needed, and appropriate measures were implemented for pest control (BRRI, 2022).

2.5 Data collection

Data was be recorded of grain yield (GY) (t/ha), growth duration (GD), plant height (PHT) (cm), thousand grain weight (TGW) (g), panicle per m^2 (PPM), filled grains per panicle (GPP), unfilled grains per panicle (UFG), and sterility percentage (STR%). Harvesting commenced when 80% of the grains were fully ripened of panicle. A designated area of 3 m by 3 m, totaling 9 m^2, was demarcated excluding the border lines of the experimental plot. Any missing hills within the sample area were carefully counted, and an equivalent number of hills from other areas outside the plot's border lines were added to the harvested sample hills to ensure accurate yield estimation for the 9 m^2 area. Subsequently, the GY was converted into t/ha. Threshing was carried out using either a pedal thresher or manually by removing leaves, straws, and other debris from the grains. The weight was accurately recorded while simultaneously measuring the moisture content of the grains, adjusting the grain yield to 14% moisture content. To determine PHT, data were collected from ten plants in each plot, measuring from the soil level to the tip of the panicle in centimeters, and then averaged. For measuring TGW, 1000 grains were manually counted from the harvested site of the experimental plot and weighed using a scale of grams. For PPM estimation, a 1 m by 1 m area was marked, and the number of panicles within the marking was counted. Ten panicles were randomly selected outside the marking for both GY and PPM, and the total number of filled grains and unfilled grains was counted. Subsequently, the total number of filled and unfilled grains was averaged to calculate the GPP and UFG. STR% was calculate by following formula,

STR% = Total unfilled grain/ (Total filled grain+ Total unfilled grain) ×100

2.6 Statistical analysis

The study employed a combined two-way analysis of variance (ANNOVA) and mean separation for genotypes, environments, and GEI using Statistics 10. The least significant difference (LSD) test was utilized to distinguish mean values at a significance level of $p < 0.05$. The genetic parameters of studied traits were analyzed using "metan" package of R software. The coefficient of correlation (Pearson's Correlation) of studied traits of rice genotypes was performed using 'metan' package of R statistical software. A heatmap for genotypes and studied traits was prepared by using "pheatmap" package of R. The AMMI analysis of variance, WAAS biplot and GGE biplot were analyzed using 'metan' package of R. The MTSI analysis was performed utilizing the "metan" package within the R statistical software environment (R studio, 2020), employing a positive selection criterion for all traits with a selection pressure set at 15%.

3. Results

3.1 Analysis of variance

Table 3 displays the combined analysis of variance (ANOVA) outcomes for eight yield and yield-related traits in six FBR-SD genotypes across eleven locations of Bangladesh during the 2022-23 boro growing season. The results indicated that all sources of variation, including replication (R), genotypes (G), locations/ environments (E), and genotype-environment interactions (GEI), had a significant impact on the traits studied ($p \leq 0.001$).

3.2 Genetic parameters of studied traits

The effect of G, E and GEI on the studied traits was found significant at $p<0.05$ based on the likelihood ratio test (LRT) of restricted maximum likelihood (REML) model (Table 4). In the linear mixed model (LMM), Table 4 presents the genetic parameters of various traits in six FBR-SD rice genotypes. The genetic variance (σ^2_g) percentages were highest for GD (50.24%) and TGW (44.27%), while environmental variance (σ^2_e) percentages were highest for GY (39.80%) and GPP (59.60%). PHT, PPM, UFG, and STR% showed the highest variance percentages for genotype-environment interaction (σ^2_{GEI}) at 53.06%, 51.37%, 49.46%, and 65.82%, respectively. The broad-sense heritability (h^2_b) ranged from 0.05 to 0.50 across the studied genotypes for the eight traits. The genetic advance in a percent of mean (GAPM) ranged from 0.47 to 0.92. Selection accuracy (SA) was high (>0.80) for all traits except UFG (0.68). The ratio of genotypic (CV_g) to residual coefficient of variation (CVr) ranged from 0.34 to 4.13.

3.3 Mean performance of FBR-SD genotypes

Table 5 presents the mean values of eight yield and yield-contributing traits for six rice genotypes. The GY was recorded for V1 at 7.29 t/ha, followed by V2 at 7.20 t/ha and V3 at 7.25 t/ha. Regarding other yield-contributing traits, V2 exhibited significantly higher values for PPM (303.73) and GPP (144.76) compared to the other genotypes, while TGW was highest in V3 (23.48 g). V4 had the shortest mean GD (138.50 days), followed by V1 (139.88 days). Additionally, V1 displayed the tallest PHT (109.81 cm), while V2 had the lowest PHT (93.33 cm). V5 exhibited the highest STR% (23.17%), while the lowest was in V6 (15.47%). The UFG was found highest in V5 at 34.74 and the lowest was in V6 (24.48).

Table 6 depicts the GEI effects on GY. Variability in GY is evident across E and G, with significant differences observed in mean yield values. The highest GY was recorded in the Natore region for the V2 genotype, reaching 9.48 t/ha, followed by V1 at 9.31 t/ha and V3 at 8.64 t/ha. Conversely, the lowest yield was observed in V5, measuring 3.77 t/ha in the Sonagazi region. The highest GY was recorded in Natore at 8.29 t/ha, followed by Sirajganj at 8.21 t/ha and Faridpur at 7.89 t/ha.

Table 3. Combined ANOVA of six FBR-SD rice genotypes during the 2022-23 boro season studied across 11 locations of Bangladesh

SV	df	Mean sum of squares							
		GY	GD	PHT	TGW	PPM	GPP	UFG	STR%
R	2	0.2023***	0.136***	7.77***	0.2377***	850.2***	305.56***	170.57***	4.157***
G	5	7.3806***	210.870***	1285.82***	44.3092***	4650.3***	3865.54***	754.60***	387.254***
E	10	17.4576***	397.371***	1426.97***	18.3079***	31984.6***	6907.52***	1457.29***	428.365***
GEI	50	1.2341***	16.785***	147.57***	3.5301***	1574.0***	802.12***	401.16***	128.658***
Error	130	0.3279***	0.321***	7.37***	0.5430***	337.4***	394.36***	93.10***	12.439***
Total	197								

R replication, G genotype, E environment/ locations, GEI genotype-environment interaction, *** significant at 0.1% level of probability, df degrees of freedom, GY grain yield, GD growth duration, PHT plant height, TGW thousand grain weight, PPM panicle per m^2, GPP grains per panicle, UFG unfilled grain, STR% sterility percentage SV: Source of variation

Table 4. Genetic parameters of yield and yield attributing traits of six FBR-SD rice genotypes studied under 11 locations in LMM

Parameters	GY	GD	PHT	TGW	PPM	GPP	UFG	STR%
σ2g (%)	22.9	50.24	39.05	44.27	11.34	15.53	5.17	13.30
σ2GEI (%)	37.30	46.81	53.06	35.36	51.37	24.87	49.46	65.82
σ2e (%)	39.8	2.94	7.90	20.37	37.30	59.60	45.37	20.88
h2b	0.23	0.50	0.39	0.44	0.11	0.16	0.05	0.13
SA	0.91	0.96	0.94	0.96	0.81	0.89	0.68	0.82
CVg	6.20	1.71	5.78	5.03	3.29	7.35	10.00	14.00
CVr	8.18	0.41	2.60	3.41	5.96	14.40	29.70	17.50
CV ratio	0.76	4.13	2.22	1.47	0.55	0.51	0.34	0.80
GAPM	0.83	0.92	0.89	0.92	0.66	0.79	0.47	0.67
LRT	*	*	*	*	*	*	*	*

σ2g genotypic variance, σ2e environmental variance, σ2GEI variance of genotype-environment interaction, h2b broad sense heritability, GEIr2 coefficient of determination of the interaction effects, SA selection accuracy, CVg genotypic coefficient of variation, CVr residual coefficient of variation, CV ratio ratio of CVg and CVr, GAPM genetic advance in a percent of mean, LRT likelihood ratio test, GY grain yield, GD growth duration, PHT plant height, TGW thousand grain weight, PPM panicle per m2, GPP grains per panicle, UFG unfilled grain, STR% sterility percentage

Table 5. Mean values of yield and yield traits for six FBR-SD rice genotypes

Genotypes	GY (t/ha)	GD (days)	PHT (cm)	TGW (g)	PPM	GPP	UFG	STR%
V1	7.29a	143.58c	109.81a	22.92b	293.83b	134.97b	26.12b	16.23d
V2	7.20a	144.97a	102.73c	21.37d	303.73a	144.76a	32.36a	20.03bc
V3	7.25a	144.38b	105.16b	23.48a	284.13c	130.97b	33.83a	20.32c
V4	6.20c	138.50f	96.67d	22.89b	288.19bc	118.34c	34.45a	22.17ab
V5	5.98c	139.88e	96.34d	22.10c	268.00d	119.68c	35.74a	23.17a
V6	6.79b	140.38d	93.33e	20.28e	289.63bc	135.25ab	24.48c	15.47d
CV%	8.23	0.40	2.67	3.33	6.25	15.16	29.52	17.58
$LSD_{0.05}$	0.28	0.28	1.32	0.36	8.95	9.67	4.7	1.72

LSD least significant differences among mean values at 5% level of significant, CV coefficient of variations, V1 BR11318-5R-63, V2BR11337-5R-72, V3SVIN109, V4IR17A1723, V5BRRI dhan81, V6BRRI dhan96, GY grain yield, GD growth duration, PHT plant height, TGW thousand grain weight, PPM panicle per m^2, GPP grains per panicle, UFG unfilled grain, STR% sterility percentage

Table 6. Mean values of grain yield (GY) (t/ha) for interaction effect of genotypes and locations during 2022-23 boro season

Locations	GY (t/ha)						
	V1	V2	V3	V4	V5	V6	LM
Barishal	6.09v-z	6.28s-x	6.36q-x	5.35yzab	4.46bc	5.81w-za	6.42d
Faridpur	8.52b-f	8.75a-d	8.61a-e	7.61f-m	7.60f-m	7.83d-l	7.89b
Gazipur	8.33c-i	7.81e-l	8.22c-j	6.92l-v	7.23l-r	7.20l-s	7.85bc
Gopalganj	8.17c-k	7.31j-p	7.75e-m	6.61n-w	7.14l-s	7.08l-t	7.50c
Habiganj	6.13u-z	6.36q-x	6.48p-x	5.58x-za	5.28zab	6.48p-x	6.09de
Kushtia	6.32r-x	6.43p-x	6.54n-w	6.00v-za	5.83w-za	6.48p-x	5.92e
Manikganj	7.25k-q	7.05l-u	7.58g-m	6.61n-w	6.43p-x	6.87m-v	6.15de
Natore	9.31ab	9.48a	8.64a-e	8.39b-g	7.79e-l	8.86abc	8.29a
Rangpur	6.59n-w	6.43p-x	6.54n-w	6.21t-y	6.43p-x	6.49o-x	5.79e
Sirajganj	8.35c-h	8.39b-g	8.50b-g	7.43h-n	7.42i-o	7.79e-l	8.21ab
Sonagazi	6.09v-z	5.87w-za	6.01v-z	4.62bc	3.77c	5.08ab	6.43d
CV%	15.29	15.38	14.18	21.81	27.11	15.68	13.82
LSD	0.92						0.38

LSD least significant differences among mean values at 5% level of significant, CV coefficient of variations, LM locational mean, V1 BR11318-5R-63, V2BR11337-5R-72, V3SVIN109, V4IR17A1723, V5BRRI dhan81, V6BRRI dhan96

3.4 Correlation analysis of among traits

Figure 4 presents the Pearson's correlation coefficients between the studied traits of rice genotypes. The traits STR and UFG exhibited a significant positive correlation (r=0.95 at p<0.001). GY showed a significant positive correlation with growth duration (GD) (r=0.89 at p<0.05). Additionally, GY and GPP were significantly positively correlated (r=0.84 at p<0.05). There was no significant negative correlation was found between studied traits.

3.5 Heatmap of genotypes' contribution to the studied traits

Figure 5 illustrates the trait contributions of different rice genotypes using a heatmap. Genotypes V1, V2, V3, and V6 positively contribute to GY. Among them, genotype V2 stands out as the highest contributor to PPM, GPP, and GD, while negatively affecting TGW. Genotypes V5 and V4 are the primary contributors to UFG and STR. Genotype V1 has the highest contribution to PHT and GY, while V3 contributes significantly to TGW. Although genotypes V4, V5, and V6 negatively influence GD, genotype V6 still positively contributes to GY.

3.6 AMMI analysis of variance

Table 7 presents the AMMI ANOVA, highlighting the contributions of different sources of variation to the total sum of squares (TSS) observed in the dataset for GY. The analysis of variance revealed that GY was significantly affected by E, G and GEI, with a p-value less than 0.001. The majority of the total sum of squares (TSS) in the model was attributed to E (174.576), followed by GEI (61.708) and G (36.903). The interaction of the first two principal components (PCs) accounted for approximately 77.5% of the variance. Among the PCs of the AMMI ANOVA, the first three PCs were significant at ≤0.01 probability, contributing to a total of 90.7% of the variance.

3.7 Stability analysis through WAAS biplot

Figure 6 presents a WAAS biplot showing the performance of six rice genotypes across eleven locations. The vertical axis represents the average GY across all environments, with genotypes to the right indicating higher GY and those to the left indicating lower GY. The horizontal axis represents the mean WAAS, dividing the biplot into four quadrants. Genotypes in different quadrants are classified based on their stability and yield performance. Quadrant I typically contain genotypes with low stability and yield, including V6, V8, and V5. Genotype V2 in quadrant II shows high WAAS values, indicating high GEI influence and high yield. Quadrants III and IV have low WAAS values, indicating high stability. Genotypes V1 and V3 in quadrant IV exhibit high GY and stability across environments. There were no genotypes fall into the quadrant III.

3.8 GGE polygonal biplot analysis for MET

Within the GGE biplot, a polygon is formed by connecting the vertex genotypes (V1, V2, V6, V4, and V5) (Figure 7). This polygon is then divided into five distinct sectors by rays (dotted lines) originating from the plot's origin and extending perpendicular to the polygon's sides. In regions where environments are located and genotypes are positioned above them, it indicates that these specific genotypes perform optimally in those particular environments.

Table 7. AMMI ANOVA of rice grain yield (GY) (t/ha) for six FBR-SD genotypes studied under 11 locations during 2022-23 boro season

Source of variations	df	TSS	MSS	PC Contribution	Total contribution
E	10	174.58	17.46***	-	-
R (E)	22	7.41	0.34	-	-
G	5	36.90	7.38***	-	-
GEI	50	61.71	1.23***	-	-
PC1	14	26.97	1.93***	43.7	43.7
PC2	12	20.87	1.74***	33.8	77.5
PC3	10	8.12	0.81**	13.2	90.7
Noise (PC)	8	5.75	0.75	9.3	-
Residuals	110	35.62	0.32	-	-
Total	247	377.92	1.53	-	-

[E] environment/ location, [R] replication, [G] genotype, [GEI] genotype-environment interaction, *** significant at 0.001% level of probability, ** significant at 0.01% level of probability, [df] degrees of freedom, [TSS] total sum of square, [MSS] mean sum of square, [PC] principal component

Table 8. Broad-sense heritability (h^2) and selection gain (SG) (%) based on factor analysis obtained through MTSI for grain yield (GY) of six rice genotypes

VAR	Factor	X_o	X_s	h^2	SG (%)	Sense	Goal
GY	FA1	6.96	7.29	0.833	3.93	increase	100
GD	FA1	142	145	0.92	1.88	increase	100
GPP	FA1	131	147	0.792	9.54	increase	100
TGW	FA2	22.1	21.4	0.92	-3.04	increase	0
UFG	FA2	32.7	35.2	0.468	3.62	increase	100
STR	FA2	20.1	21.3	0.668	4.22	increase	100
PPM	FA3	294	311	0.662	3.91	increase	100
PHT	FA4	102	103	0.885	1.48	increase	100

[Xo] observed mean, [Xs] mean of selected genotypes, [FA] factor, [GY] Grain yield, [GD] Growth Duration, [PHT] Plant Height, [TGW] thousand grain weight, [PPM] Panicle per m^2, [GPP] Grains per panicle, [UFG] Unfilled grain, [STR%] Sterility percentage

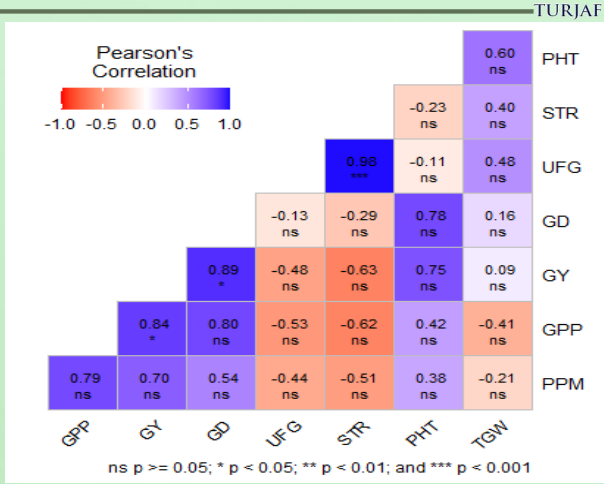


Figure 4. Co-efficient of correlation among traits of six FBR-SD rice genotypes. ^{GY} grain yield, ^{GD} growth duration, ^{PHT} plant height, ^{TGW} thousand grain weight, ^{PPM} panicle per m^2, ^{GPP} grains per panicle, ^{UFG} unfilled grain, ^{STR} sterility percentage

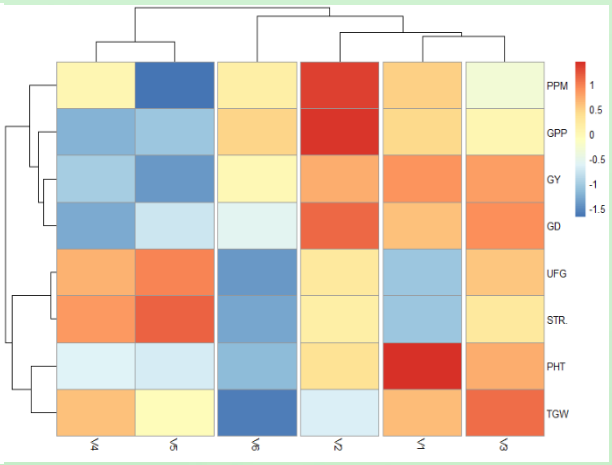


Figure 5. Heatmap of six rice genotypes and eight yield and yield related traits. ^{GY} grain yield, ^{GD} growth duration, ^{PHT} plant height, ^{TGW} thousand grain weight, ^{PPM} panicle per m^2, ^{GPP} grains per panicle, ^{UFG} unfilled grain, $^{STR\%}$ sterility percentage



Figure 6. WAAS biplot of AMMI stability model with stability and mean performance of grain yield (GY) (t/ha).

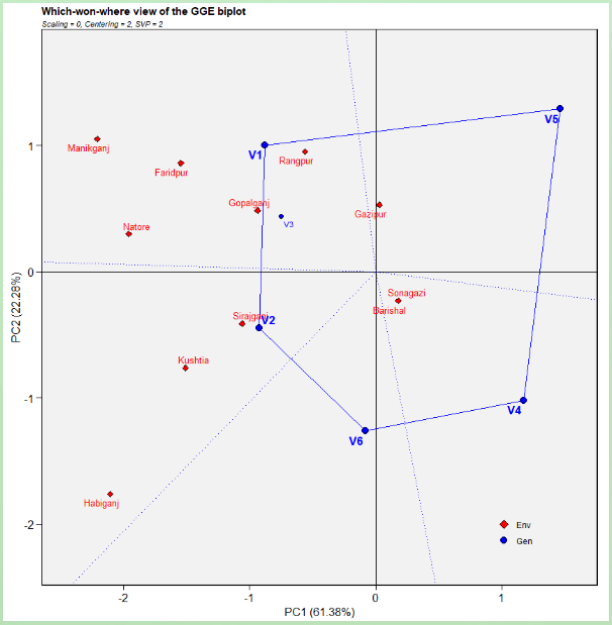


Figure 7. Polygonal view of GGE biplot for winner genotype in respective environment/ location for grain yield (GY) (t/ha).

Genotypes located in areas without any environments are considered unsuitable for cultivation in the examined environments and are classified as weak genotypes in most environments. Genotype V2 demonstrated superior GY performance in Sirajganj, Kushtia, and Habiganj, while Genotypes V1 and V3 showed desirable GY in Manikganj, Faridpur, Natore, Gopalganj, and Rangpur. Additionally, V4 performed well in the Sonagazi and Barishal environments, while V5 excelled in the Gazipur region. However, Genotype V6 was positioned without any associated environment.

3.9 Multitrait stability index (MTSI)

Table 8 displays the results of the factor analysis, which reveal the broad sense heritability (h^2), selection gain percentage (SG) (%), desired selection sense, and the achievement status of the goal based on factor analysis of selected rice genotypes using eight traits. The factor analysis revealed that contributing factors formed into three distinct groups consisting of eight traits under study. The desired selection sense was to increase for all traits. The goal was successfully achieved for all traits, with the exception of TGW. Among the studied traits, the h^2 was highest for GD and TGW (0.92), followed by PHT (0.885) and GY (0.833). Furthermore, the SG (%) for studied traits was ranged from 1.48 to 9.54 %. The selected genotype, however, possesses a negative SG (%) in TGW (-3.04%).

Figure 8 presents the representation of the order of the most stable genotype determined by the multi-trait stability indexing (MTSI). Within this context, the red circle symbolizes the threshold for selecting the stable genotype. The rice genotype named V2 stands out as the most stable compared to other genotypes.

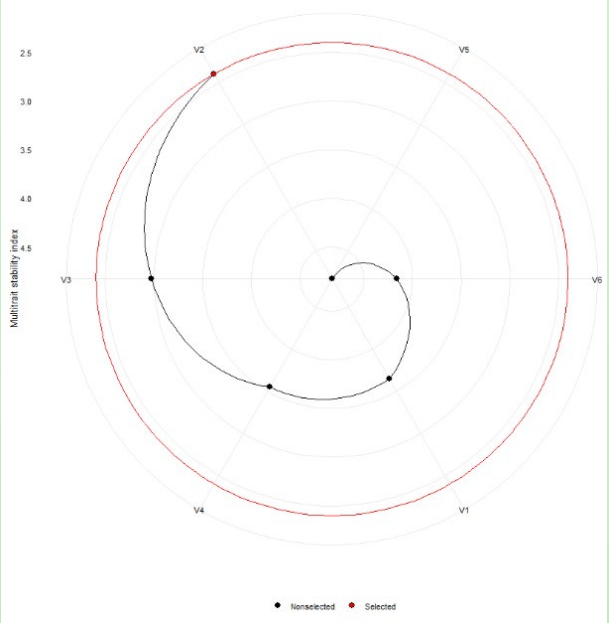


Figure 8. Ranking of genotype stability based on MTSI index

4. Discussion

The study observed significant variations in yield and its attributing traits among different genotypes (G), environmental/locational conditions (E), and genotype-environment interactions (GEI) (Table 3). The percentages of genotypic (σ2g), environmental (σ2e), and GEI variance (σ2GEI) in Table 4 confirm the differences observed in the studied traits. The success of crop breeding programs largely depends on genetic diversity and the transmission of desirable characteristics. Analyzing the genetic diversity of a species with the involvement of plant breeders can lead to the enhancement of commercially desirable traits (Sarker, 2020). To assess genetic diversity, researchers often utilize σ2g, σ2e, and σ2GEI, as well as coefficients of variation (CV) (Baraki et al., 2020; Khan et al., 2024). A CV ratio of genotypic CV (CV g) and residual CV (CV $_r$) higher than 1 indicates high genetic diversity, while a lower ratio suggests low genetic diversity (Sharma et al., 2021). In this study, the CV ratios for growth duration (GD), plant height (PHT), and thousand grain weight (TGW) were all above 1, indicating high genetic diversity. Moreover, these traits exhibited high broad-sense heritability (h^2_b) and selection accuracy (SA) (Table 4). Traits with high genetic diversity, h^2_b, and SA suggest potential for improvement through trait-based selection (Alam, Akter, Khan, Alam, et al., 2024; Alam, Akter, Khan, Amin, et al., 2024; Alam, Akter, Khan, Rashid, et al., 2023; Hasan et al., 2020). High h^2_b combined with a high percentage of genetic advance relative to the mean (GAPM) is important for trait selection in breeding programs. In this study, GD, PHT, and TGW showed both high h^2_b and high GAPM, indicating additive gene action, thus making them suitable targets for rice improvement. Previous studies have also reported similar findings regarding high h^2_b and GAPM for various yield-related traits (Sarker, 2020). Except for grain yield (GY), the traits showed high GAPM, suggesting the influence of both additive and non-additive gene actions in trait expression. This aligns with findings from other research on rice (Faysal et al., 2022).

Yield and its contributing traits of rice are influenced by various factors (Kiniry et al., 2001; Kumar et al., 2017). According to Sarker et al. (Sarker, 2020), genotype plays a significant role in determining rice yield and its contributing characteristics, although numerous factors such as meteorological conditions, soil texture, nutrient composition, and genetic traits also influence these traits (Dou et al., 2016; Xuan et al., 2019). Boro rice cultivation, typically practiced in irrigated ecosystems due to low rainfall during the boro growing season (Mainuddin et al., 2021), tends to perform better in coarse-textured soils compared to fine-textured soils, despite careful farmer management practices (Bhuyan et al., 2023; Frimpong et al., 2023). In our study, locations like Natore, Sirajganj, and Faridpur exhibited the highest average grain yield for FBR-SD rice genotypes, indicating the presence of favorable environmental conditions in those areas. Rice varieties exhibit substantial variation in the duration from sowing to harvest (Vergara et al., 1966). In our study, the average GD significantly differed among rice genotypes, with the V4 genotype displaying the shortest GD. Opting for a short-duration crop offers numerous advantages over a long-duration one, even if their total grain yields are equivalent. A shorter-duration crop requires less water per cycle, faces reduced exposure to risks such as pests, diseases, droughts, and storms, and extends the window

for subsequent plantings of rice or other crops (Vergara et al., 1966). PHT also varied among rice genotypes, consistent with findings by Zhang et al. (Zhang et al., 2017), who highlighted the role of the OsMPH1 gene in regulating plant height. They observed that high OsMPH1 expression in rice nodes and pulvini, and its nuclear localization, led to increased plant height through cell elongation in internodes. TGW exhibited significant variability across rice genotypes, as reported by Zuo et al. (Zuo et al., 2022), who identified OsMADS56 as the gene responsible for a QTL affecting grain weight and size. Wang et al. (Wang et al., 2024) proposed increasing panicle numbers as a viable strategy to enhance rice yield potential, noting that the Lemont genotype showed a substantial increase in panicle count, albeit with a decrease in grain numbers. Discrepancies in filled grain per panicle (GPP) and panicles per m^2 (PPM) underscore the genetic basis of these traits, aligning with our study's findings. Unfilled grain (UFG) and grain sterility (STR%) varied significantly with genotype and environmental conditions. Elevated temperature coupled with high humidity at heading induces nearly complete grain sterility in rice, with a 30% reduction in relative humidity at high temperatures resulting in decreased grain sterility (De Abeysiriwardena et al., 2002; Osada et al., 1973). Puteh et al. (Puteh et al., 2014) observed significant genotype-dependent variation in UFG and STR%.

The correlation among traits facilitates the identification of specific traits that, through indirect selection, can enhance overall yield performance. Heatmap analysis provides a practical evaluation of the direct and indirect influences of each trait associated with the genotypes. The primary economic trait, GY, demonstrated a significant positive correlation with GPP in our study, consistent with previous findings (Kayastha et al., 2022; Wang et al., 2024). In the present study, there was no significant correlation between GPP and Additionally, GD showed a significant positive correlation with GY. Genotypes V1, V2, V3, and V6 were identified as the top contributors to GY (Figure 5), suggesting that enhancing GPP in these genotypes may lead to improved GY performance. According to Huang et al. (Huang et al., 2018), rice yield tends to increase with prolonged GD, although some rice cultivars with shorter GD also exhibit high GY (Chen et al., 2019), indicating the potential for high GY in short-duration cultivars as well. In our study, V6 negatively contributed to GD but positively contributed to GY. Okamura et al. (Okamura et al., 2018) found a positive and significant correlation between STR% and UFG, consistent with our study findings.

AMMI analysis revealed that the error mean sum of squares for GY was lower compared to G, E, and GEI, indicating the model's accuracy. Studies by Abdelrahman et al. (Abdelrahman et al., 2022) and Sharifi et al. (Sharifi et al., 2017) supported this observation. Additionally, Fathi Sadabadi et al. (Sadabadi et al., 2018) and Hassani et al. (Hassani et al., 2023) found that the first and second principal components (PCs) of GEI collectively explained 71.60% of the variability, aligning closely with our study's findings (77.5%). Understanding GEI assists in decision-making regarding adaptation to different environmental conditions, as noted by Ghazy et al. (Ghazy et al., 2024) and Lee et al. (Lee et al., 2023). The WAAS biplot differs from the AMMI model in that it incorporates all scores of the PCs rather than focusing solely on the first two. Genotypes with low WAAS values falling into quadrant IV in the biplot are identified as high yielding and stable, according to Ghazy et al. (Ghazy et al., 2024). In our WAAS biplot analysis, considering both GY and WAAS values, genotypes V1 and V3 emerge as superior performers with stable performance. In a similar rice genotype study, Ghazy et al. (Ghazy et al., 2024) categorized the WAAS biplot into four categories: high-yielding stable, high-yielding not stable, low-yielding stable, and low-yielding unstable genotypes. This classification aids rice breeders in predicting the genotypic performance of each genotype under study before integrating them into different programs, which aligns with our study findings.

Utilizing a GGE polygonal biplot, as recommended by Gauch and Zobel (Gauch & Zobel, 1997), assists in suggesting suitable genotypes for specific environments. In our study, the biplot identified five mega-environments among 11 tested locations for GY. Among these, five locations (Manikganj, Natore, Faridpur, Gopalganj, and Rangpur) were deemed favored environments for genotype V1, characterized by conducive environmental conditions and soil properties for optimal rice growth. Akter et al. (Akter et al., 2015) also observed similar outcomes and identified appropriate genotypes for specific environments using GGE biplot analysis. Moreover, among the 11 environments assessed, genotype V2 exhibited superior performance in three environments (Sirajganj, Kushtia, and Habiganj), while V5 showed favorable performance only at Gazipur, and V4 displayed good performance in Sonagazi and Barishal. These results underscore the significant influence of GEI on the performance of tested genotypes. GEI negatively impacted the performance of evaluated genotypes by compromising their yield under unfavorable conditions. This observation is corroborated by the findings of other studies, such as those by Liang et al. (Liang et al., 2015) and Singh et al. (Singh et al., 2023). Conversely, V6 demonstrated poor performance in all tested environments, indicating its unsuitability across the eleven locations studied. This finding aligns with the conclusions drawn by Ghazy et al. (Ghazy et al., 2024).

The selection process considers variations among characteristics in relation to their level of hereditary influence. The relationship between broad sense heritability (h^2) and genetic gain (SG) is a crucial factor in breeding programs, as there is a direct association between the h^2 of traits and the increase in SG (Alam, Akter, Khan, Amin, et al., 2024). Chattopadhyay et al. (Chattopadhyay et al., 2011) indicated that traits with h^2 exceeding 60% are considered highly heritable, those with 30 to 60% are moderately heritable, and those with 0 to 30% are lowly heritable. Our findings reflect this pattern, with h^2 demonstrating high values for all traits except UFG.

Additionally, the SG for the studied traits was also notably high. This suggests that direct selection of genotype V2 could effectively enhance the studied traits in rice cultivation. However, for TGW, although the aim of selection was positive, the selection goal was not met, resulting in a negative SG, which is considered desirable for rice varietal selection in the context of Bangladesh (Choudhury, 1979; Mottaleb & Mishra, 2016). The slender grain type exhibits low TGW due to the reduced individual weight of rice grains. The MTSI index was computed based on eight attributes related to yield and its contributing characteristics to rank stable genotypes with higher mean trait values. Several researchers have employed the MTSI index for selecting stable genotypes of rice and other crops (Alam, Akter, Khan, Rashid, et al., 2023; Lee et al., 2023; Olivoto et al., 2019; Sharifi et al., 2017). These findings align with the results obtained from our investigation, where genotype V2 emerged as the top-ranked stable genotype.

5. Conclusions

The extensive evaluation of advanced rice lines and reference varieties across various locations during the 2022-23 boro season unveiled significant impacts of genotype, environment, and their interactions on yield and associated traits. V1 exhibited the highest grain yield, closely trailed by V2 and V3, with V3 showing remarkable performance. Natore stood out as the location with the highest yield, and grain yield showed a positive correlation with growth duration and filled grain per panicle. Heatmap analysis revealed favorable contributions to yield from V1, V2, V3, and V6. The WAAS and GGE biplot emphasized the stability and adaptability of different genotypes across locations, with V2 emerging as the top stable genotype using MTSI. Factor analysis showcased promising results for most traits, with significant broad-sense heritability observed for growth duration, plant height, and grain yield. Overall, this study offers valuable insights into genotype performance and stability across diverse environments, aiding in the selection and breeding of high-yielding boro rice varieties. It's important to acknowledge the study's limitation of being conducted for a single growing season, potentially overlooking annual variability in environmental conditions such as climate, soil, and pest pressures. Hence, a comprehensive, multi-seasonal investigation incorporating identified genotypes is recommended to enhance the reliability and precision of results. Considering the alignment of traits with stability analysis, ARD, BRRI proposes advancing the V2 genotype for proposed variety trials with MEs before finalizing its release.

Declarations

Ethical Approval Certificate

The experimental procedures of this study were approved by the authority of Bangladesh Rice Research Institute, 1701, Gazipur, Bangladesh.

Author Contribution Statement

*Mir Mehedi Hasan: Data collection, supervision, conceptualization, methodology, Analyzed and interpreted the data, writing the original draft, review and editing

Shamsunnaher: Data collection, supervision, conceptualization, methodology and investigation

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Conflict of Interest

"The authors declare no conflict of interest."

Data availability statement

Data will be made available on request.

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Abbreviations and Units

BRRI: Bangladesh Rice Research Institute, BRR: Blast resistant rice, RCBD: Randomized complete block design, GEI: Genotype-environment interactions, GGE: Genotype and Genotype-Environment, PCA: Principal component analysis, ANOVA: Combined analysis of variance, PBD: Plant Breeding Division, GY: Grain yield, PHT: Plant height, PPM: panicle per meter^2, DTM: Growth duration, GPP: Grains per panicle, TGW: 1000-grain weight, FGP: Filled grains per panicle, UFG: Unfilled grains per panicle, STR: sterility percentage, CV: Coefficient of variation, AMMI: Additive Main Effects and Multiplicative Interaction, WAASB: Weighted Average of Absolute Scores from the BLUPs, MTSI: Multi-Trait Stability Index.

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Evaluation of the Relationship Between Condensed Tannin Content and Rumen Protein Degradability in Sainfoin (*Onobrychis viciifolia*)

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Abstract

Condensed tannins, naturally occurring polyphenolic compounds present in certain legumes such as sainfoin (*Onobrychis viciifolia*), can bind dietary proteins at ruminal pH levels. These tannin-protein complexes resist microbial degradation in the rumen but dissociate in the acidic environment of the abomasum, thereby enhancing amino acid absorption in the small intestine. This study aimed to evaluate the relationship between condensed tannin content and ruminal protein degradability in sainfoin, with a focus on the potential role of condensed tannins in protecting dietary proteins from microbial breakdown. Twenty-five sainfoin samples, harvested as green forage from various regions of Türkiye at 50–100% flowering stage, were used in this study. Crude protein content was determined according to the AOAC (2003) method 954.01, while condensed tannin content was measured using the hydrochloric acid (HCl)-butanol assay. Effective protein degradability of the samples was assessed using the *in situ* nylon bag technique, following the method of Ørskov and McDonald (1979). The effective protein degradability values, calculated at a ruminal outflow rate of k = 0.06 h^{-1}, ranged from 53.7% to 62.5%, indicating variability in protein degradation characteristics among the samples. Correspondingly, condensed tannin content ranged from 34.2 to 50.9 g kg^{-1} dry matter. Regression analysis revealed a strong negative linear relationship between condensed tannin concentration and effective protein degradability, with a coefficient of determination (R^2) of 0.80. These findings suggest that condensed tannins play a significant role in reducing ruminal protein degradation by forming stable tannin-protein complexes, thereby enhancing the potential for feed proteins to bypass the rumen and be absorbed in the small intestine as undegraded protein.

Key Words: *Sainfoin, Condensed tannins, Protein, Rumen degradability*

Introduction

Tannins are phenolic compounds known for their strong ability to bind proteins and other macromolecules, forming stable complexes (Mangan, 1988). By protecting dietary proteins from microbial breakdown, these complexes reduce both the rate and extent of protein degradation in the rumen (McSweeney et al., 1988; Min et al., 2001). Tannins bind forage proteins at the neutral pH of the rumen, forming complexes that resist microbial enzymatic activity. These complexes then dissociate in the acidic environment of the abomasum, releasing proteins for digestion and thus enhancing nitrogen utilization efficiency (Jones & Mangan, 1977; Waghorn & Shelton, 1995; Hudson, 2001).

Tannins are typically classified into two main groups: hydrolysable tannins (HT) and condensed tannins (CT). Condensed tannins, also known as proanthocyanidins, are polymers of flavan-3-ols that yield colored anthocyanidins when treated with acidified alcohol (Mueller-Harvey & McAllen, 1992). While HT can be toxic to ruminants, CT are generally considered non-toxic or less harmful due to their poor absorption in the gastrointestinal tract.

Forage legumes containing CT have been shown to stabilize dietary proteins in the rumen by reducing proteolysis, thereby allowing more intact protein to bypass the rumen and reach the abomasum (Kingston-Smith et al., 2004). This bypass protein, also known as rumen undegraded protein (RUP), is then digested and absorbed in the small intestine. Differences in protein degradation rates among legume species have been used to assess the impact of tannins on ruminal proteolysis (Broderick & Albrecht 1994). In CT-containing forage plants, protein–tannin complexes are formed during mastication, limiting microbial access to plant proteins. These complexes resist microbial degradation in the rumen and pass intact to the abomasum, where they dissociate at low pH, making the proteins available for digestion and absorption in the small intestine (Woodward, 2000).

Sainfoin (*Onobrychis viciifolia*) is among the most prominent CT-rich forage legumes. Due to its CT content, sainfoin typically shows lower ruminal protein degradability than other forages, such as alfalfa (Van Soest, 1994). In sainfoin, CT are distributed across most plant tissues except for the cotyledons and roots, with the highest concentrations found in the leaves (Less et al., 1993; 1995). Concentrations of CT ranging from 5% to 8% of dry matter have been reported to reduce protein solubility and limit degradation in the rumen (Waghorn et al., 1998).

Tannin-rich legumes reduce ruminal protein degradation and improve nitrogen utilization efficiency (Reid et al., 1974; Egan & Ulyatt, 1980). For example, CT in sainfoin and birdsfoot trefoil have been associated with improved protein metabolism and digestibility in ruminants (Reed, 1995). Thomson et al. (1971) reported greater protein utilization from dried sainfoin compared to alfalfa, attributing this to its tannin content. As such, sainfoin is

recognized as a valuable source of bypass protein. Its low ruminal protein degradability enables more protein to reach the small intestine intact for digestion and absorption (Wilkins & Jones, 2000).

Multiple studies have demonstrated that CT in sainfoin reduce ruminal protein breakdown, lower ammonia concentrations, and increase the flow of bypass protein and amino acids to the duodenum (Hart & Sahlu, 1993; Broderick & Albrecht, 1997; McMahon et al., 2000; Broderick, 2001; Wang et al., 2003). The inhibitory effect of CT on ruminal protein degradation increases proportionally with tannin concentration (Broderick & Albrecht, 1997), and has been associated with residual dry matter (DM) and crude protein (CP) after incubation (Julier et al., 2003). Protein degradability in buffer and *in vitro* systems has shown a strong negative correlation with tannin levels (Hedqvist, 2004). In sainfoin silage, higher CT levels have significantly reduced total tract nitrogen digestibility and *in situ* nitrogen degradability in sheep, especially in early-flowering silages (Theodoridou et al., 2012). A significant negative relationship between CT content and effective protein degradability (DE) has also been reported (Azuhnwi et al., 2012), with CT concentrations being negatively correlated with rapidly degradable fraction (a) and degradation rate of the slowly degradable fraction (c) (Aufrère et al., 2014). Similarly, increased CT levels in early-stage sainfoin were found to reduce ruminal CP degradability and nitrogen digestibility (Özbilgin, 2019).

Accordingly, the aim of this study was to evaluate the relationship between CT content and DE in sainfoin samples collected from different regions of Türkiye during the same vegetative stage. In this context, the hypothesis of the study was that naturally varying levels of CT in sainfoin samples grown in different regions would have a significant effect on ruminal protein degradability, and that increasing tannin content would lead to decreased protein degradability.

Materials and Methods

Experimental forages and chemical analyses

In the present study, twenty-five samples sainfoin (*Onobrychis viciifolia*) were harvested as green forage from various regions of Türkiye, were used. The samples were harvested at 50-100% flowering period. Forage samples collected were dried in an air-forced oven at 60°C for at least 72 hours until a constant weight was achieved, then ground to pass through a 1-mm screen using a Retsch mill (Retsch GmbH, Haan, Germany) and analyzed for DM (930.15), and CP (954.01) according to AOAC (2003) methods. The CT content was determined by the hydrochloric acid (HCl)-butanol assay (Reed, 1986).

In situ disappearance in the rumen

The ruminal degradation of CP was evaluated using the nylon bag technique. Dacron bags (Ankom Co., Macedon, NY, USA), with a pore size of 53 ± 15 µm and an internal surface area of 5 × 11 cm, were heat-sealed after being filled with approximately 4 g of air-dried sainfoin samples (1 mm mesh) collected at the 50–100% flowering stage. These bags were incubated in the rumen of three cows maintained on a diet consisting of 70% hay and 30% concentrate (DM basis). *In situ* degradation was measured at incubation times of 4, 8, 16, 24, 48, 72, and 96 h. Dehydrated lucerne samples, used as a standard, were incubated in duplicate in the rumen of each cow to monitor potential changes in ruminal degradation activity throughout the experiment. After removal from the rumen, the bags were thoroughly rinsed and stored at −20°C until further analysis. Prior to analysis, they were thawed and washed in a household washing machine with cold water (three cycles of 10 minutes each) until the rinse water became clear. Finally, the bags were dried at 60°C for a duration of 72 hours.

In situ CP rumen disappearance curves of samples were fitted to the model of Ørskov & McDonald (1979) using a non-linear regression procedure (SAS, 2000):

$$P = a + b\,(1 - e^{-ct})$$

where P is the potential degradable, a is the rapidly degradable fraction, b is the slowly degradable fraction, e is the base of the natural logarithm, c is the degradation rate of the slowly degradable fraction, and t is the incubation time. The residual fraction was calculated as $(100 - a - b)$.

The effective protein degradability (DE) was estimated using the following equation:

$$DE = a + bc / (c + kp)$$

where kp, the fractional passage rate, was assumed to be 0.06/h.

Statistical analysis

A simple linear regression analysis was conducted using SAS Version 8.0 Statistical Package (SAS Institute Inc., Cary, NC, USA) to determine the relationship between content of CT and DE.

Results and Discussion

The distribution of DE values of sainfoin samples is presented in Figure 1. The effective protein degradability values of samples, calculated at a ruminal outflow rate of k = 0.06 h^{-1}, ranged from 53.7% to 62.5%, with a mean of 58.1%. The majority of the values were clustered within the 56% to 60% range, indicating that the DE of sainfoin was minimally affected by environmental factors.

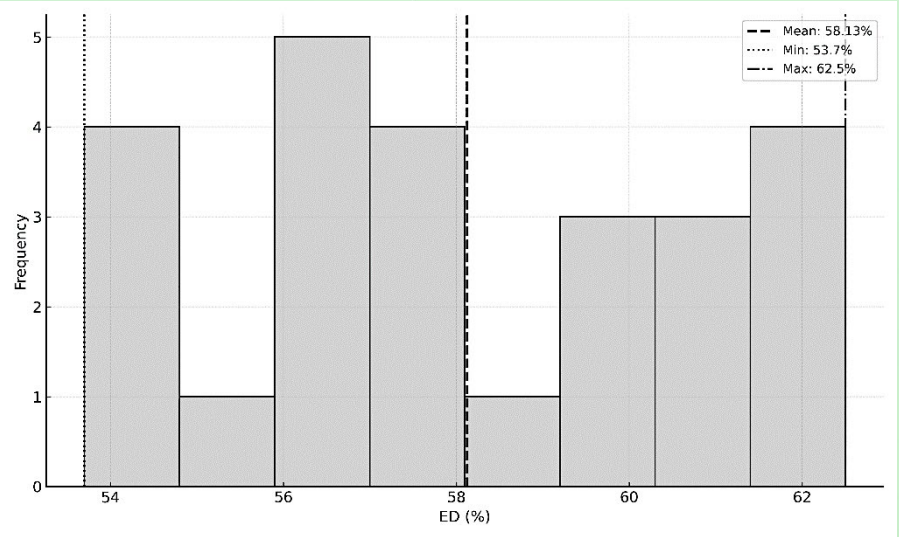


Figure 1. Distribution of effective protein degradability values of sainfoin

These results indicated that sainfoin generally exhibited a moderate level of ruminal protein degradability. In various studies, the DE of sainfoin has typically been reported within the range of 53% to 61%, which is lower than that of more commonly used forage legumes such as alfalfa (Ocak, 1997; Sarıçiçek & Kılıç, 2002; Hanoglu, 2004, Azuhnwi et al., 2012; Aufrère et al., 2014). This difference is primarily attributed to the presence of CT in sainfoin, which are known to form stable complexes with proteins. These complexes limit microbial proteolysis in the rumen and promote the transfer of undegraded protein to the abomasum and small intestine, thereby enhancing bypass protein availability (Jones & Mangan, 1977; Waghorn et al., 1987; McSweeney et al., 1988). Aufrère et al. (2014) reported that tannin-rich forages such as sainfoin exhibit significantly lower DE values compared to tannin-free species, a difference attributed to the interaction between CT and the molecular structure of plant proteins.

Effective protein degradability can be influenced by various factors such as plant species (Turgut & Yanar, 2004), growth stage and harvest time (Aufrère et al., 2014), and forage structure and chemical composition (Broderick & Albrecht, 1997). However, since all sainfoin samples used in this study belonged to the same cultivar and were harvested at similar developmental stages, the DE values exhibited only limited variation.

The distribution of CT content in sainfoin is presented in Figure 2. Condensed tannin concentrations varied between 34.2 and 50.9 g·kg^{-1} DM, averaging 43.0 g·kg^{-1} DM. The data demonstrate a narrow variability, suggesting that most samples had similar CT levels within the given range. Tannin levels in plants can differ substantially not only between species but also among tissues and developmental stages within a species. Their concentrations are modulated by various environmental factors such as drought, soil nutrient status, pH, herbivore pressure, ozone exposure, and atmospheric CO_2 levels (Kraus et al., 2003). In line with this, CT levels in sainfoin have also been shown to vary depending on the plant variety, the location where it is grown, and the timing of harvest (Azuhnwi et al., 2011).

Azuhnwi et al. (2012) reported that CT contents in different sainfoin varieties ranged from 26.6 to 57.3 g·kg^{-1} DM, with this variation being largely attributed to genetic differences, while environmental influences were considered limited. Aufrère et al. (2014) reported CT contents ranging from 35.5 to 48.6 g·kg^{-1} DM across three sainfoin cultivars grown under the same conditions, suggesting that variation was primarily attributable to genetic differences rather than environmental factors. Theodoridou et al. (2012) reported CT concentrations ranging from 33.1 to 51.4 g·kg^{-1} DM in sainfoin silages, and found that both the CT content and its biological activity were affected by the phenological stage at harvest. Özbilgin (2019) reported that CT content in sainfoin increased with advancing maturity, with the highest levels observed at full flowering and the lowest at the budding stage.

The relationship between CT content and DE in sainfoin samples is presented in Figure 3. The derived linear regression equation is:

$y = -0.54x + 81.42$

where y is effective protein degradability, x is condensed tannin content.

This equation indicates that for every 1 g·kg^{-1} DM increase in CT content, the DE value decreases by approximately 0.54 percentage points. This result highlights the inhibitory effect of tannin compounds on protein degradability. The coefficient of determination was calculated as $R^2 = 0.80$, $P = 0.001$, suggesting that 80% of the variation in DE can be explained by differences in CT levels. This high R^2 value demonstrates that the regression model provides a strong fit to the data. Furthermore, the distribution of data points closely around the regression line supports the appropriateness of a linear model. These findings confirm a strong and statistically meaningful inverse relationship between CT content and DE in sainfoin.

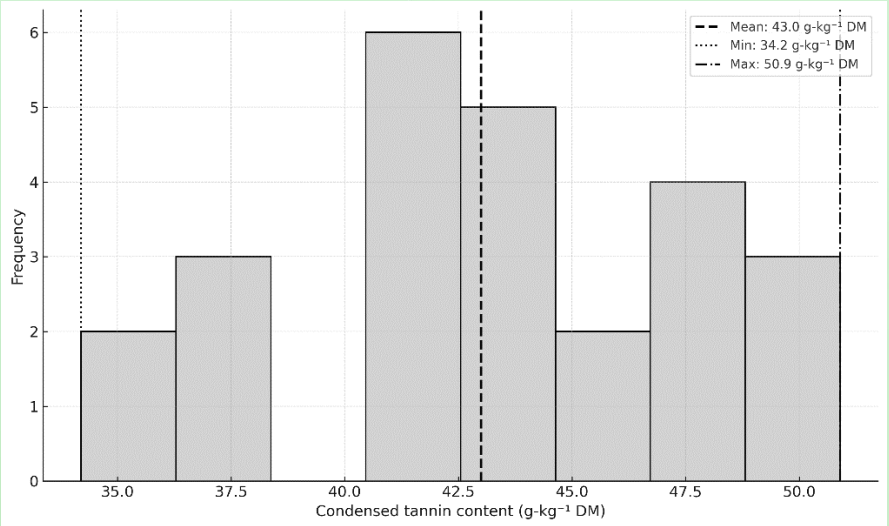


Figure 2. Distribution of condansed tannin content of sainfoin

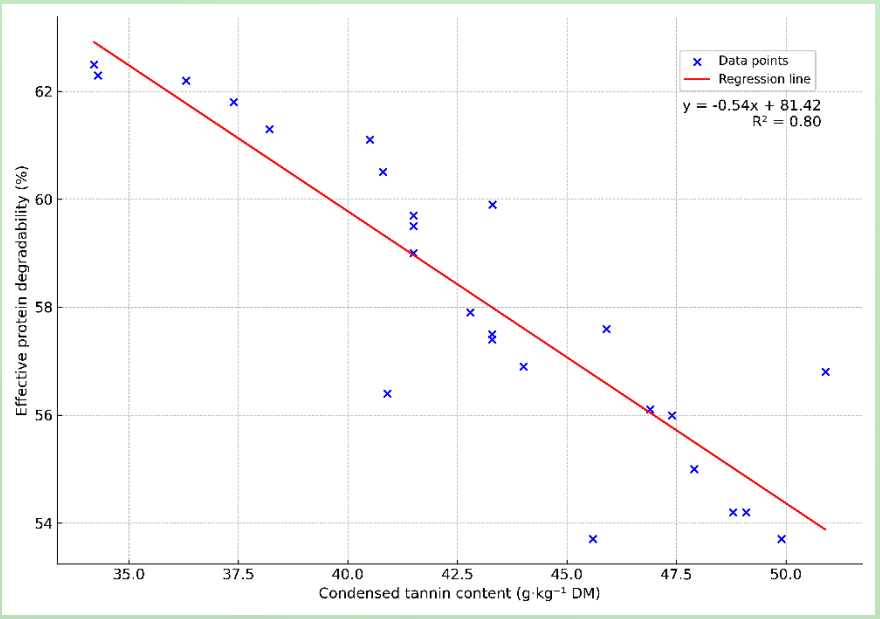


Figure 3. Relationship between condensed tannin content and effective protein degradability in sainfoin

Similarly, the literature clearly demonstrates that CT have a direct inhibitory effect on protein degradability in the rumen. Tannins form strong complexes with proteins under rumen pH, making them resistant to microbial degradation; these complexes then dissociate in the acidic environment of the abomasum, rendering the proteins digestible and thereby increasing the proportion of by-pass protein (Barry et al., 1986; Mangan, 1988; McSweeney et al., 1988; Waghorn et al., 1987, 1994; McNabb et al., 1996; Beck, 2001; Min et al., 2001, 2002).

Azuhnwi et al. (2012) reported that as the CT content increased in sainfoin, the DE significantly ($R^2 = 0.36$, $P = 0.003$) decreased. They noted that this relationship was generally linear and that the reduction in protein degradability was more pronounced in samples from the second harvest. Aufrère et al. (2014) reported a strong negative correlation ($r = -0.81$) between ruminal nitrogen degradability and CT content. Condensed tannins was shown to inhibit both the rapidly degradable nitrogen fraction (a) and the degradation rate of the slowly degradable fraction (c). These results indicate that CT can reduce the rate of protein breakdown in the rumen and potentially enhance the proportion of by-pass protein. Similar findings were reported by Theodoridou et al. (2012), clearly demonstrating that CTs in sainfoin silage have a direct inhibitory effect on protein digestibility.

Conclusion

This study revealed a statistically significant negative relationship between CT content and DE in sainfoin. The increase in CT levels was associated with reduced ruminal protein degradability, indicating that sainfoin can be considered a valuable forage source in terms of bypass protein. However, excessive levels of condensed tannins

may have adverse effects on animal performance and should be carefully evaluated. Therefore, as long as CT content remains within nutritionally appropriate limits**,** sainfoin not only enhances protein utilization efficiency in ruminant nutrition but also stands out as a promising forage crop that supports sustainable livestock production systems thanks to its drought tolerance and adaptability to environmental stress under the challenges of climate change.

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Constraints in Aromatic Rice Cultivation: Insights from Smallholder Farmers of Northern Bangladesh

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Abstract

Though Bangladesh a south asian country takes pride in being home to exclusive fine aromatic rice, it has done precious little to retain this much-valued product. The traditional varieties with excellent aroma are almost at the verge of extinct from the fields. The purpose of this study was to determine farmers' constraints in aromatic rice production, and to explore the relationship between the selected characteristics of the farmers with their constraints in aromatic rice production. Data were collected using pre-designed and pre-tested structured interview schedule from a sample of 92 farmers out of 653 farmers selected by simple random sampling procedure. The data collection was done in Uthrail unions of sadar upazila under Dinajpur district. Besides the usual descriptive statistical parameter, Pearson's Product Moment Correlation Coefficient (r) was used for the statistical analysis. About three-fourths (67.3 percent) of the respondents had faced medium constraint while 20.7 percent had low constraints and only 12.0 percent had faced high constraints. Among the constraints, "Diseases" (CFI= 270.6) was found the first ranked constraints in aromatic rice production faced by the farmers. The lowest constraints in aromatic rice production faced by the farmers was 'Erosion' (CFI= 78.2) among the selected constraints. According to the computed value of correlation coefficients (r), among ten selected characteristics of the farmer's age, education, family size, farm size and annual income had no significant relationship with farmers' constraints in aromatic rice production. On the other hand, area under aromatic rice cultivation, agricultural knowledge, extension media contact, training received and aspiration had positive significant relationship with farmers' constraints in aromatic rice production.

Key Words: *Constraints, Aromatic rice, Farmers' and Northern Bangladesh*

Introduction

The slogan "rice is life" is most appropriate for Bangladesh as it is the most widely consumed grain and key to the food security of the nation. In Bangladesh, there are about more than 7,000 varieties of rice are grown in various parts of the country (Shamsi, *et al.*, 2010). In general, rice is classified by its length, thickness and aroma. The length of long-grain rice is four to five times that of its width. One of the more exotic varieties in the long-grain is the aromatic East Indian Basmati and Kalijira rice. It was mentioned by various historians that Bengal was famous for spices, Kalijira and Moslin fabrics. Rice is the staple food of half the world's population that contributes to 20% of the total man caloric intake (Bhattacharjee *et al.*, 2002). Nevertheless, total caloric intake for the Asian population is around 40% to 80% where 95% of world rice production comes from Asian countries such as China, India, Indonesia, Bangladesh, Vietnam and India. The biggest rice exporter is Thailand with 9.8 million tons of rice export per year (BRF, 2015). World trade figures are very different to those for production, as only about 5% to 7% of rice produced is traded internationally. Due to the small volume, the price of rice can rise sharply when something happens to the major exporter countries such as the uncertainty of the climate conditions that will affect the rice production (Ghosh, 2008; Walker, 2008) and impose restricting export. Fragrant rice (Basmati and Jasmine type) shows the highest price in the world market and accounts for about 15% to 18% of world trade. About 70 percent of the world's poor live in rural areas and mostly depend on agriculture as the main source of income and employment (World Bank, 2010). Rice alone contributes of 97% of the food grain production in Bangladesh (BBS, 2013). The quantity of rice traded is relatively small, about 4 to 5 percent of total production. Among different groups of rice, transplant aman (T. Aman) rice cover about 49.11% of total rice area and it contributes to 38.11% of the total rice production in the country (BBS, 2013). In Bangladesh, rice dominates over all other crops and covers 75% of the total cropped area (Rekabdar, 2004) of which around 27% is occupied by fine rice varieties (BBS, 2003).

Different varieties of rice have different characters. Rice grain is categorized into coarse, medium coarse and fine with different color based on physical properties. Some of them have special appeal for their aroma. There are two type of transplant aman rice viz. coarse and fine rice and some of the fine rice are aromatic. The major aromatic varieties identified are Kalijira, Chinigura, Kataribhog, BR5, Bashful, BRRI dhan 34, BRRI dhan 37, BRRI dhan 38 (Bashmotitype), Khaskani, Badshabhog, Dudshagar, Tulshimala, Khirshabhog, Horibhog, Parbatjira, Khasha, Modhumadab, Tilkapur, Chinikanai, Khirkon and Shakhorkora. Some of the features of Kataribhog rice are: this variety is fine quality rice, scented, and sweet to taste, nutritious, delicious. Aromatic rice is generally low yielding (Gangaiah and Prasad, 1999) but they are considered best in quality and also highly valued. Aromatic rice is now an important commodity in international trade having small grain with pleasant aroma. Aromatic rice of

Bangladesh on account of its high export potential and its taste as well as better eating quality like polau, khir, firny, paish, chira, khoi, biriany etc. have great demand. Milled aromatic rice is also used as popular food in ceremonies like marriage day, Eid day etc. According to Bangladesh Rice Exporters Association (BREA) statistics, Bangladesh exported 700 metric tons of aromatic rice in 2001, 780 metric tons in 2002, 1000 metric tons in 2003, and 3300 metric tons in 2004. Export value of aromatic and fine rice stood at 200,000 US dollars in 2003-2004 fiscal years. So, the production of aromatic rice in the country is economically profitable.

The above facts indicate that there is a need for an investigation aiming at an understanding on the constraints faced by the farmers in aromatic rice cultivation. However, very few systematic investigations have been done in this context. Hence, the researcher undertook a study relating to the constraints faced by the farmers in aromatic rice cultivation. The research work was conducted with the following objectives:

a) To determine and describe the selected characteristics of farmers. The characteristics were: age, education, family size, farm size, area under aromatic rice cultivation, annual income, agricultural knowledge, extension media contact, training received and aspiration.

b) To determine farmers' extent of constraints in aromatic rice production.

c) To explore the relationship between the selected characteristics of the farmers with their constraints in aromatic rice production.

d) To know the suggestions provided by the farmers to overcome the constraints.

Methodology

Study areas

The present study was conducted in 7 no Uthrail union of Sadar upazila under Dinajpur district. There are 13 upazilas in Dinajpur district. Among these, sadar upazila is one of the agriculturally important upazila where rice, wheat, maize, vegetables are intensively cultivated along with plantation. Most of the farmers of this area are directly and/or indirectly engaged in agricultural activities and few people are service holders and businessmen.

Design of the study

Designing the research for the present study was taken in a scientific manner. Firstly, different research themes are collected and analyzed followed by research problem formulation. Reviews were studied to select appropriate variables and preparation of questionnaire. Pretesting of the interview schedule was done before final data collection. Finally data were collected, analyzed and report was prepared.

Data collection tools and technique

In order to collect desired information, an interview schedule was prepared keeping the objectives of the research in mind. The schedule was prepared in Bangla for better understanding of the respondents. The questions included were simple and direct to ascertain the opinion of the farmers regarding a number of aspects. Simple random sampling procedure was followed in this study. Dinajpur district was purposively selected due to a number of reasons: Firstly, the districts have the highest percent and area under Kataribhog rice and secondly investigator's familiarity in the area, language and culture of the people. Among the 13 Upazilas, Dinajpur sadar was selected by purposive sampling procedure because aromatic is mostly cultivated in this upazila. One union of sadar upazila namely 7 no. Uthrail was selected by random sampling procedure from 10 unions. An up-to-date list of 653 aromatic rice producing farmers was prepared with the help of the Upazila Agriculture Office of the DAE. From these farmers, 92 (about 15 percent) were selected as the sample by using simple random sampling procedure. A reserve list of 10 farmers (about 10 percent) was prepared so that these farmers could be used for interview in case any farmer included in the original sample was not available in spite of utmost effort during collection of data.

Measurement of farmers' constraints in aromatic rice production

Farmers' constraints in aromatic rice production were the major focus of the study. Thus farmers' constraint in aromatic rice production was the focus issue of this research work. The respondent was asked to express their opinion on the extent of constraints in each of 15 mentioned constraints along a 4-point rating scale; 'not at all (0)', 'low (1)', 'medium (2)', and 'high (3)'. The responses of the scale was given scores as 3 for 'high', 2 for 'moderate', 1 for 'low' and 0 for 'not at all'. The summation of the scores against all the 15 mentioned constraints express the farmers' opinion towards constraints.

For comparative analysis of constraints a "Constraints Facing Index" was calculated by using the following formula:

Constraints Facing Index (CFI) = C_{hi} x 3 + C_{mo}x 2 + C_l x 1 + C_{na} x 0

Where,

C_{hi} = Percentage of farmers opined constraint as high

C_{mo} = Percentage of farmers constraint as moderate

C_l = Percentage of farmers opined constraint as low

C_{na} = Percentage of farmers opined constraint as not at all.

In respect of any perception "Constraints Facing Index" could range from 0 to 300, where 0 indicating no constraint and 300 indicating high constraint.

Statistical analysis

The analysis was performed using Statistical Package for Social Science (SPSS) computer package. Descriptive analysis such as range, number, percentage, mean, standard deviation and rank order were used whenever necessary. For clarity of understanding tables were also used for presenting the data. Pearson's Product Moment Correlation Co-efficient (r) was used to examine the relationships of independent variables of the respondents with the perception of the farmers towards constraints in aromatic rice production.

Results and Discussion

The results of the study are presented in this chapter with the help of proper statistical analysis along with their logical interpretations. This study has been conveniently presented in three sections according to the objectives. The first section deals with the selected characteristics of the farmers. The second section deals with the perception of the farmers towards constraints in aromatic rice production and the third section deals with the relationships between the selected characteristics of the farmers with the perception of the farmers towards constraints in aromatic rice production.

Characteristics of the Respondents

Many characteristics of farmers may have influence to their constraints in aromatic rice production. However, only 10 characteristics namely age, education, family size, farm size, area under aromatic rice cultivation, annual income, agricultural knowledge, extension media contact, training received and aspiration are included in this study. It was assumed that the farmers with their constraints in aromatic rice production would vary according to their various characteristics. The salient features of the different characteristics have been presented in Table 1.

Table 1. Salient features of the selected characteristics of the farmers (N=92)

Characteristics	Scoring method	Range	Categories	Respondents		Mean	SD
		Observed (Possible)		No.	Percent		
Age	No. of year	10-60 (Unknown)	Young aged (≤35)	44	47.8	38.17	12.06
			Middle aged (36-50)	33	35.9		
			Old aged (>50)	15	16.3		
Education	Year of schooling	0.0-17 (Unknown)	Illiterate (0)	32	34.8	5.63	5.13
			Can sign only (0.5)	2	2.2		
			Primary level (1-5)	10	10.9		
			Secondary level (6-10)	34	37.0		
			Above secondary level (>10)	14	15.2		
Family size	No. of members	2-9 (Unknown)	Small (≤ 3)	9	9.8	5.71	1.87
			Medium (4-6)	50	54.3		
			Large (>6)	33	35.9		
Farm size	Hectare	0.07-8 (Unknown)	Marginal (0.02-0.20)	5	5.4	1.53	1.70
			Small (0.21-1.0)	46	50.0		
			Medium (1.01-3.0)	28	30.4		
			Large (>3.0)	13	14.1		
Area under aromatic rice cultivation	Hectare	0.04-8 (Unknown)	Marginal (0.02-0.20)	24	26.1	1.30	1.29
			Small (0.21-1.0)	26	28.3		
			Medium (1.01-3.0)	36	39.1		
			Large (>3.0)	6	6.5		
Annual income	('000' Tk.)	40.2-840 (Unknown)	Low income (≤50)	22	23.9	188.17	183.84
			Medium income (51-250)	48	52.2		
			High income (>250)	22	23.9		
Agricultural knowledge	Score	8-18 (0-25)	Fair (≤8)	15	16.3	13.40	3.00
			Good (9-16)	66	71.7		
			Excellent (>16)	11	12.0		
Extension media contact	Score	2-29 (0-36)	Low (≤12)	19	20.7	14.32	7.26
			Medium (13-24)	57	62.0		
			High (>24)	16	17.4		
Training received	No. of days	0-10 (unknown)	No (0)	44	47.8	1.43	2.17
			Short (≤2)	32	34.8		
			Medium (3-7)	12	13.0		
			Long (>7)	4	4.3		
Aspiration	Score	10-29 (6-30)	Low (≤10)	15	16.3	23.35	6.36
			Medium (11-20)	67	72.8		
			High (>20)	10	10.9		

Age

The age of the respondents ranged from 10 to 60 years with a mean of 38.17 and standard deviation of 12.06. According to age the farmers were classified into three categories are 'young aged' (up to 35), 'middle aged' (36-50) and 'old aged' (>50) based on their observed score (Table 1).

Data contained in Table 1 reveals that about half (47.8 percent) of the respondents were young aged compared to 35.9 percent of the respondents belonged to the middle-aged categories and 16.3 percent were in the old aged category. These findings indicated that the majority of the farmers were young aged. The findings imply that the aromatic rice farmers were young and middle-aged groups.

Education

The educational qualification scores of the farmers ranged from 0.0 to 17, the mean being 5.63 and standard deviation 5.13. Based on educational qualification scores the respondents were classified into five categories such as 'illiterate' (0) 'can sign only' (0.5), 'primary level' (1-5), 'secondary level' (6-10) and 'above secondary level' (>10) as presented in Table 1.

Data presented in Table 1 indicate that highest proportion (37.0 percent) of the farmers had secondary education, 34.8 percent were illiterate, 2.2 percent were can sign only, 10.9 percent had primary education and 15.2 percent of the farmers had above secondary education level. The finding indicated that 65.2 percent of the respondents were educated. The average literacy rate in Bangladesh is 72.76 percent (Dhaka Tribune, 2017). So, the education rate of the study area is lower than the average literacy rate in the country.

Family size

The family size scores of the farmers ranged from 2 to 9. The average family size was 5.71 with a standard deviation of 1.87. The respondents were classified into three categories like 'small' (≤3), 'medium' (4-6) and 'large' (>6) are presented in Table 1.

The data furnished in the Table 1 revealed that more than half (54.3 percent) of the respondents had medium family size, 9.8 percent had small family size and 35.9 percent had large family. The national average family size in Bangladesh is 4.85 (BBS, 2014) which is near the mean value of the present study (5.71). It is quite logical that prevalence of joint family system in the study area might have also contributed to the large family size.

Farm size

The farm size scores of the farmers ranged from 0.07 to 8, the average being 1.53 and standard deviation 1.70. The farmers were classified into four categories as 'marginal' (0.02-0.20), 'small' (0.21-1.0), 'medium' (1.01-3.0) and 'large' (>3.0) as shown in Table 1.

Data presented in Table 1 show that exactly half (50.0 percent) of the respondents were small farm size, 5.4 percent were marginal farm size, 30.4 percent had medium farm size and 14.1 percent had large farm size. Most of the farmers had medium farm size. Moreover, it enriches their perception towards improved farming practices and enlightens power of understanding and abilities to analyze facts and situations to make appropriate decisions on farming activities.

Area under aromatic rice cultivation

The farm size under aromatic rice cultivation scores of the farmers ranged from 0.04 to 8, the average being 1.30 and standard deviation of 1.29. The farmers were classified into four categories as 'marginal' (0.02-0.20), 'small' (0.21-1.0), 'medium' (1.01-3.0) and 'large' (>3.0) as shown in Table 1.

Data presented in Table 1 show that most of the (39.1 percent) of the respondents were medium farm sized, 26.1 percent were marginal farm size, 28.3 percent had small farm size and 6.5 percent had large farm size. Most of the farmers (67.4 percent) had small to medium farm size. This means that the aromatic rice growers are the scenario on the basis of farm size.

Annual income

The family income scores of the farmers ranged from 40.2 to 840 with a mean of 188.17 and standard deviation of 183.84. Based on the annual income the farmers were classified into three categories such as 'low income' (≤50), 'medium income' (51-250), 'high income' (>250) as shown in Table 1.

Data furnished in Table 1 indicate that a little more than half (52.2 percent) of the farmers had medium income compared to 23.9 percent under low and only 23.9 percent under high income group. The overwhelming (76.1 percent) of the respondents were under low to medium income category.

Agricultural knowledge

Agricultural knowledge scores of the growers varied from 8 to 18 against a possible range of 0 to 25. The average agricultural knowledge score was found to be 13.40 and standard deviation was 3.00. Based on the observed overall knowledge scores, the respondents were classified into three categories as 'fair' (≤8), 'good' (9-16), and 'excellent' (>16) as shown in Table 1.

Data presented in Table 1 shows that about three-fourths of the (71.7 percent) of the respondents had good agricultural knowledge compared to 16.3 percent had fair knowledge and only 12.0 percent had excellent agricultural knowledge. A respondents who receives high level of education but less involvement in farming might possess lower knowledge than the growers who is actively involved in farming for a long period of time.

Extension media contact

The extension contact scores of the farmers ranged from 2 to 29, against the possible score 0 to 36. The mean and standard deviation were 14.32 and 7.26 respectively. The respondents were classified into three categories based on their extension contact as 'low' (≤12), 'medium' (13-24) and 'high' (>24) as shown in Table 1.

Data presented in Table 1 shows that majority (62.0 percent) of the farmers had medium extension media contact, 20.7 percent had low extension contact and 17.4 percent had high extension contact. The findings indicate that above three-fourths (79.4 percent) of the farmers had medium to high extension media contact. This may be due to the reason that the respondents contact highly with different extension media.

Training received

The training received scores of the respondents ranged from 0 to 10 with a mean of 1.43 and standard deviation of 2.17. According to the training received scores, respondents were classified into four categories like 'no training' (0), 'short' (≤2), 'medium' (3-7) and 'long' (>7) in Table 1.

Data presented in the Table 1 revealed that 47.8 percent of the respondents had no training followed by 34.8 percent received short training, 13.0 percent received medium training and 4.3 percent received long training. Training increases skills and knowledge which makes the respondents much more competent in performing different activities.

Aspiration

The aspiration scores of the farmers ranged from 10 to 29 against the possible range 6 to 30 with a mean and standard deviation of 23.35 and 6.36 respectively. Based on their aspiration scores, the respondents were classified as 'low' (≤10), 'medium' (11-20) and 'high' (>20) which is presented in the Table 1.

It is revealed from the Table 1 that the highest proportion (72.8 percent) of the respondents had medium aspiration, 16.3 percent of the respondents had low and only 10.9 percent of the respondents had high aspiration respectively. Findings showed that majority of the farmers possessed their aspiration and the result might be due to the effect of better educational qualification, better communication system of the respondents.

Farmers' Constraints in Aromatic Rice Production

For having the better understanding regarding farmers constraints in aromatic rice production, it was necessary to have an idea about the comparative constraints in 15 selected constraints. For this purpose, Constraint Facing Index (CFI) was computed. The computed CFI of the 15 constraints ranged from 78.2 to 270.6 against a possible range from 0 to 300 which are arranged in rank order according to their CFI as shown in Table 2.

Table 2. Distribution of farmers according to constraints of aromatic rice production

Sl. No.	Constraints	Percentage of farmers				*CFI	Rank order
		Not at all	Low	Medium	High		
A.	**Biotic constraints**						
1.	Weeds	3.3	6.5	20.6	69.6	256.5	2
2.	Rodents	4.3	8.7	35.9	51.1	233.8	4
3.	Diseases	0	1.1	27.2	71.7	270.6	1
4.	Insects	2.2	20.7	12	65.1	240	3
B.	**Abiotic constraints**						
5.	Drought	28.3	15.2	48.9	7.6	135.8	12
6.	Erosion	37	48.9	13	1.1	78.2	15
7.	Heat Stress	31.5	48.9	13	6.6	94.7	13
8.	Soil Fertility	23.9	19.6	52.2	4.3	136.9	11
C.	**Socioeconomic constraints**						
9.	Difficulties to access to credit	5.4	25	52.2	17.4	181.6	7
10.	Unavailability of labour	13	14.1	63	9.9	169.8	10
11.	High price of seed	60.9	8.7	17.4	13	82.5	14
12.	Low market price	7.6	21.7	52.2	18.5	181.6	8
13.	High transportation cost	10.9	16.3	48.9	23.9	185.8	6
D.	**Extension service related constraints**						
14.	Insufficient regular information from extension worker	8.7	20.7	35.9	34.7	196.6	5
15.	Lack of new technology in aromatic rice cultivation	5.4	18.5	66.3	9.8	180.5	9

***CFI= Constraints Facing Index**

Data in Table 2 indicate that "Diseases" (CFI= 270.6) was found the first ranked constraints faced by the farmers. All the farmers of the study are aromatic rice cultivars. They cultivate aromatic rice for high profit but high yielding varieties are not available all time. 'Weeds' was found as the second ranked (CFI= 256.5) constraints faced by the farmers. The result may be due to that weed control is the vital factor for good yield of crop. 'Insects' (CFI= 240.0) was emerged as the third most important constraints among the selected constraints. The farmers opined that insect reduce the yield of rice. The lowest constraints faced by the farmers was 'Erosion' (CFI= 78.2) among the selected constraints. The result may be due to that there have very little challenges about erosion.

Overall farmers' constraints in aromatic rice production

Overall constraint scores for 15 selected constraints in aromatic rice cultivation could theoretically range from 0 to 45, where 0 indicating no constraint and 45 indicating high constraint. However, the observed constraint scores of the respondents ranged from 18 to 34 with a mean of 26.25 and standard deviation 3.24. Based on their constraint scores, the respondents were classified into three categories viz. 'low' (up to 23), 'medium' (24-30) and 'high' (above 30) has been presented in the Table 3.

Table 3. Distribution of the farmers according to their overall constraints in aromatic rice production

Categories (score)	Respondents (N=92)		Mean	Standard Deviation
	Number	Percent		
Low (up to 20)	19	20.7	26.25	3.24
Medium (21-30)	62	67.3		
High (above 30)	11	12.0		

Data furnished in the table 3 revealed that near about three-fourths (67.3 percent) of the respondents face medium constraint while 20.7 percent had low constraint and only 12.0 percent had high constraint. The average (mean) value of the constraint indicates that the respondents in average had medium constraints faced in aromatic rice cultivation. So, from this finding, it can be said that the desired level dissemination of aromatic rice cultivation technology will not occur if the constraints of the respondents are not minimized by the concerned authority.

Relationship between the Selected Characteristics of the respondents and farmers' constraints in aromatic rice production

This section deals with the relationship between the 10 selected characteristics of the respondents and farmers' constraints in aromatic rice production. The relationships were computed by using the Pearson's product moment correlation co-efficient(r). The co-efficient of correlation (5 percent level) was used to test the null hypothesis and analysis is presented in Table 4.

Table 4. Relationship between dependent and independent variables

Dependent variable	Independent variables	Pearson Correlation (r) values with 90 df
Farmers' constraints in aromatic rice production	Age	-0.032
	Education	-0.131
	Family size	0.082
	Farm size	0.096
	Area under aromatic rice cultivation	0.227*
	Annual income	-0.047
	Agricultural knowledge	0.277**
	Extension media contact	0.264*
	Training received	0.214*
	Aspiration	0.300**

* = Correlation is significant at the 0.05 level, ** = Correlation is significant at the 0.01 level

Age and farmers' constraints in aromatic rice production

The correlation coefficient between age of the respondents and farmers' constraints in aromatic rice production was -0.032 (Table 4). Based on the computed 'r' value the relationship between age and farmers' constraints in aromatic rice production was negative. Hence, the concerned null hypothesis could not be rejected. Thus, it could be said that the age of the respondents had no significant role on farmers' constraints in aromatic rice production.

Education and farmers' constraints in aromatic rice production

The correlation coefficient between education of the respondents and farmers' constraints in aromatic rice production was -0.131 (Table 4). Based on the computed 'r' value the relationship between education and farmers' constraints in aromatic rice production was negative and not significant with 90 degrees of freedom. Hence, the

concerned null hypothesis could not be rejected. Thus it could be said that the educational qualification of the respondents had no significant relationship with the farmers' constraints in aromatic rice production.

Family size and farmers' constraints in aromatic rice production

The computed value of correlation coefficient (r) between family size of the respondents and farmers' constraints in aromatic rice production was 0.082 (Table 4). Based on the computed 'r' value the relationship between family size and farmers' constraints in aromatic rice production was positive and not significant with 90 degrees of freedom. Hence, the concerned null hypothesis could not be rejected. Thus, it could be said that the family size of the respondents had no relationship with the farmers' constraints in aromatic rice production.

Farm size and farmers' constraints in aromatic rice production

The computed value of correlation coefficient (r) between farm size of the respondents and farmers' constraints in aromatic rice production was 0.096 (Table 4). Based on the computed 'r' value the relationship between farm size and farmers' constraints in aromatic rice production was positively not significant with 90 degrees of freedom. Hence, the concerned null hypothesis could not be rejected.

Area under aromatic rice cultivation and farmers' constraints in aromatic rice production

The computed value of correlation coefficient (r) between area under aromatic rice cultivation of the respondents and farmers' constraints in aromatic rice production was 0.227 (Table 4). Based on the computed 'r' value the relationship between farm size under aromatic rice cultivation of the respondents and farmers' constraints in aromatic rice production was positive and significant with 90 degrees of freedom at 0.05 level of probability. Hence, the concerned null hypothesis could be rejected. The data revealed that the higher the farm size under aromatic rice cultivation the higher constraints of the farmers in aromatic rice production.

Annual income and farmers' constraints in aromatic rice production

The computed value of correlation coefficient (r) between annual income of the respondents and their farmers' constraints in aromatic rice production was -0.047 (Table 4). Based on the computed 'r' value the relationship between family income of the respondents and farmers' constraints in aromatic rice production was negative and not significant with 90 degrees of freedom. Hence, the concerned null hypothesis could not be rejected. Thus, it could be said that the family income of the respondents had no significant relationship with constraints in aromatic rice production.

Agricultural knowledge and farmers' constraints in aromatic rice production

The computed value of correlation coefficient (r) between agricultural knowledge of the respondents and farmers' constraints in aromatic rice production was 0.277 (Table 4). Based on the computed 'r' value the relationship between agricultural knowledge farmers' constraints in aromatic rice production was positively significant at 0.01 level of probability with 90 degrees of freedom. Hence, the concerned null hypothesis could be rejected. Thus it could be revealed that the higher agricultural knowledge the higher constraints in aromatic rice production.

Extension media contact and farmers' constraints in aromatic rice production

The correlation coefficient between extension media contact of the respondents and their farmers' constraints in aromatic rice production was 0.264 (Table 4). Based on the computed 'r' value the relationship between extension contact of the respondents and farmers' constraints in aromatic rice production was positively significant at 0.05 level of probability with 90 degrees of freedom. Hence, the concerned null hypothesis could be rejected. Thus it could be revealed that the higher extension media contact the higher constraints in aromatic rice production.

Training received and farmers' constraints in aromatic rice production

The correlation coefficient between training received among the respondents and their farmers' constraints in aromatic rice production was 0.214 (Table 4). Based on the computed 'r' value the relationship organizational participation of the respondents and constraints of aromatic rice production was positively significant at 0.05 level of probability with 90 degrees of freedom. Hence, the concerned null hypothesis could be rejected. Thus, it could be revealed that the higher training received the higher the farmers' constraints in aromatic rice production.

Aspiration and farmers' constraints in aromatic rice production

The correlation coefficient between aspiration of the respondents and their farmers' constraints in aromatic rice production was 0.300 (Table 4). Based on the computed 'r' value the relationship aspiration of the respondents and farmers' constraints in aromatic rice production was positively significant at 0.01 level of probability with 90 degrees of freedom. Hence, the concerned null hypothesis could be rejected. Thus, it could be revealed that the higher aspiration the higher the farmers constraints in aromatic rice production.

Suggestions offered by the farmers to overcome the constraints

Many suggestions were offered by the farmers to overcome the constraints in aromatic rice production. These are given in Table 5.

It is evident from the data contained in the table 5 that 'Develop high resistance varieties to pests and diseases' (70.65 percent) were found as the most important suggestions to overcome the problems in aromatic rice production. The lowest numbers of farmers opined that 'Easy access of credit facility from bank' (22.82 percent) among the mentioned suggestions.

Table 5. Rank order of suggestions offered by the farmers to overcome the constraints in aromatic rice production

Sl. No.	Suggestions	Respondents	
		Number	Percent
1.	Develop high resistance varieties to pests and diseases	65	70.65
2.	Quality seed and fertilizer should be available	57	61.95
3.	Marketing channel of aromatic rice should be developed	43	46.73
4.	Organizing more training program for the farmers	37	40.21
5.	Easy access of credit facility from bank	21	22.82

Conclusions

Based on the findings and their logical interpretations in the light of relevant facts the researcher has drawn the following conclusions:

1. "Diseases" (CFI= 270.6) was the first ranked constraints faced by the farmers whereas 'Erosion' (CFI= 78.2) was the last ranked constraints faced by the farmers. Based on this findings it may be concluded that this scenario may be due to that farmers faced disease oriented problem frequently and farmers remain concerned more on this issue but erosion is not familiar at farmers level.
2. About three-fourths (67.3 percent) of the respondents had faced medium constraints while 20.7 percent had low constraints and only 12.0 percent had high constraints in aromatic rice cultivation. From this findings it can be concluded that majority of the farmers are aware about the constraints they faced during production of aromatic rice.
3. Among the ten selected characteristics of the farmer's, area under aromatic rice cultivation, agricultural knowledge, extension media contact, training received and aspiration showed positive significant relationship with farmers constraints in aromatic rice production. So, this may be concluded that these characteristics of the farmers should be taken under consideration and played important role in case of constraints faced by the farmers.

Recommendations

The following recommendations were made on the basis of the findings, related conclusions and their logical interpretations.

1. The farmers' constraints in aromatic rice production should be overcome by taking adequate measures. Different Government and Non-Government authority should take initiatives so that the participants get the financial help and necessary agricultural inputs at very easy and short process. Necessary supports for the farmers to increase household income are essential from the authority.
2. Relatively younger farmers who are more democrats in decision making, thus relatively younger target participant could be selected for aromatic rice cultivation because they can easily take decision in any challenging situation.
3. The farmers mentioned a number of constraints in different extent which they faced during aromatic rice cultivation. The authority should consider these facts during formulation of any program.
4. Adequate training of the farmers will help to mitigate the constraints in aromatic rice production.
5. Government should take special emphasis on the necessary supportive measures for ensuring easy availability of inputs needed for aromatic rice production at reasonable prices.

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Seed scarification relieves weed seed dormancy in *Convolvulus arvensis*

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Abstract

Field bindweed (*Convolvulus arvensis* L.) is a perennial weed, which has a creeping growth habit and deep root system. This is one among the most troublesome and aggressive weeds around the world and infest a large number of field crops and orchards. The weed has a strong dormancy character, which makes working on this weed under laboratory conditions a difficult task. This study aimed to check the dormancy breaking impact of several hormones and scarification with sand paper in the seeds of *C. arvensis*. The results showed that the most effective treatment for removing weed seed dormancy in *C. arvensis* was the mechanical method i.e., scarification with sand paper. This method resulted in a 55% germination of the weed seeds, which was the highest among all the germinated seeds. None of the hormones was effective in improving the germination of *C. arvensis*. The most efficient among the hormones was kinetin that resulted only in 5% germination of the weed seeds, which was equal to the germination percentage observed in the control treatment. It is concluded that the mechanical scarification can act as a successful method to remove dormancy in the seeds of *C. arvensis*.

Key Words: *Dormancy, Field bindweed, Weeds, Weed control, Hormones*

Introduction

The discipline of crop protection includes protecting the crops from a wide variety of pests such as viruses, disease pathogens, nematodes, rodents, weeds and insect pests. Weeds hold a significance among the different crop enemies owing to their large number, high competitive ability and resilience (Ahmad et al. 2023). High seed production and dormancy in seeds are the other characteristics of weeds that make them a tough pest (Gaba et al. 2017; Batlla et al. 2020).

Several of the weed species have been recognized as noxious or troublesome due to the great degree of damage caused by these weeds. Field bindweed (*Convolvulus arvensis* L.) is one among such weeds that infests several crops and is highly difficult to control (Davis et al. 2018). This weed belong to the Convolvulaceae family, possesses a perennial life cycle and a creeping growth habit, and propagates both vegetatively and through seeds (Sosnoskie et al. 2020). The dormancy character of the seeds of this plant make it a resilient weed (Ma et al. 2023). The dormancy in the seeds of this weed is mainly caused by its hard seed cover that does not allow the movement of moisture into the seed (Jayasuriya et al. 2008). There is a possibility to apply scarification, which is a mechanical method of removing dormancy from any plant seeds (Rocha et al. 2022). The process of seed scarification can be done either through sand paper or using some other appropriate tools. Other than this, several hormones may also play a role in germinating the dormant weed seeds. A few among such hormones are indole-3-butyric acid (IBA), 6-benzylaminopurine, benzyl adenine (BAP), gibberellic acid and kinetin (Xiong et al. 2018).

The presence of dormancy in the *C. arvensis* seeds not only provides a persistence in the nature but also creates hurdles when researchers intends to use these seeds in their laboratory or greenhouse experiments. Hence, this study was aimed to evaluate different seed dormancy breaking methods to remove dormancy from the seeds of *C. arvensis*. Determing such methods will be helpful in germinating this weed easily under laboratory conditions for the subsequent research studies.

Materials and Methods

This study was conducted at the weed science laborator of the Department of Plant Production and Technologies, Faculty of Agricultural Sciences and Technologies, Nigde Omer Halisdemir University, Nigde, Turkiye.

The seeds of the weed *C. arvensis* were collected from environments such as apple orchards, potato fields and non-cropped areas during August to October 2024. The laboratory work was conducted during the months of January to February 2025. The weed seeds were surface sterilized with a deterjan at the start of the experiment. The dormancy status of the weeds seeds was checked through a germination test. This germination test was done by putting 10 weed seeds on a filter paper in three 9-cm diametered petri dishes (i.e., replicated thrice). The seeds were watered appropriately and allowed to germinate for two weeks in an incubator at 25 °C. As the *C. arvensis* seeds were found dormant after this initial experiment, subsequently the following experiment was conducted.

Four hormones and one mechanical method were applied to check their efficacy to break dormancy in *C. arvensis*. The weed seed dormancy breaking treatments included the followings. (1) Control (no treatment) i.e., treatment

only with distilled water, (2) Scarification of the weed seeds with sand paper, i.e., application of a mechanical method for removal of the weed seed dormancy. Further, the four hormonal treatments were: (3) Treatment of the weed seeds with indole-3-butyric acid (IBA), (4) Treatments of the weed seeds with 6-benzylaminopurine, benzyl adenine (BAP), (5) Treatment of the weed with gibberellic acid (GA3), and (6) Treatment of the weed seeds with kinetin. The sand paper used for mechanical scarification of the weed seeds was obtained from a local market. The solutions of the hormones used in the study were prepared in the laboratory and stored in a 500 ml conical flask until used in the study. The salts of these chemicals (IBA, BAP, gibberellic acid, kinetin) were dissolved in distilled water to obtain solutions with a strength of IBA = 20 mg/L, BAP = 20 mg/L, gibberellic acid = 8 mg/L, and kinetin = 8 mg/L.

The experiment was conducted according to the completely randomized design with four replication. The petri dishes were fitted with a double layer of filter paper and 10 weed seeds were arranged in each petri dish. The control treatment was applied with distilled water while others were applied with the relevant hormonal solution. A five ml of a solution was applied to the relevant petri dishes, which were checked thoroughly to top-up the solution if required.

The experiment was continued for a period of 15 days and the number of germinated seeds was noted upon the termination of the experiment. Any seed producing a radicle of >2 mm was considered as germinated seed. Germination percentage was calculated based on the number of germinated seeds. Moroever, the other parameters including shoot length, root length and seedling height were measured with meter rod. The seedling fresh weight was recorded by weighing the seedlings on a sensitive balance.

The data corrected were processed through Microsoft Excel. The program was used to calculated the means and standard errors of the replicated data. The mean data was represented as bar charts, which were fitted with their relevant error bars to be used to compare the significance of difference among the treatment means.

Results

None of the seeds of *C. arvensis* were germinated in a germination test conducted to check the dormancy of the weed seeds (data not presented). As all of the weed seeds were dormant, subsequently the dormancy breaking treatments were applied on *C. arvensis* seeds. The results showed that the effect of dormancy breaking treatments was significant on the germination of *C. arvensis*, and the treatments had a variable effect on the weed germination (Figure 1). Seed scarfication with sand paper was the most effective treatment, which resulted in the highest weed seed germination (55%) while none of the hormonal treatments were effective in improving germination in *C. arvensis* seeds. Kinetin and BAP were the only two hormonal treatments that resulted in some germination but this was only 5% or less than it, and was similar with the germination achieved in the control treatment.

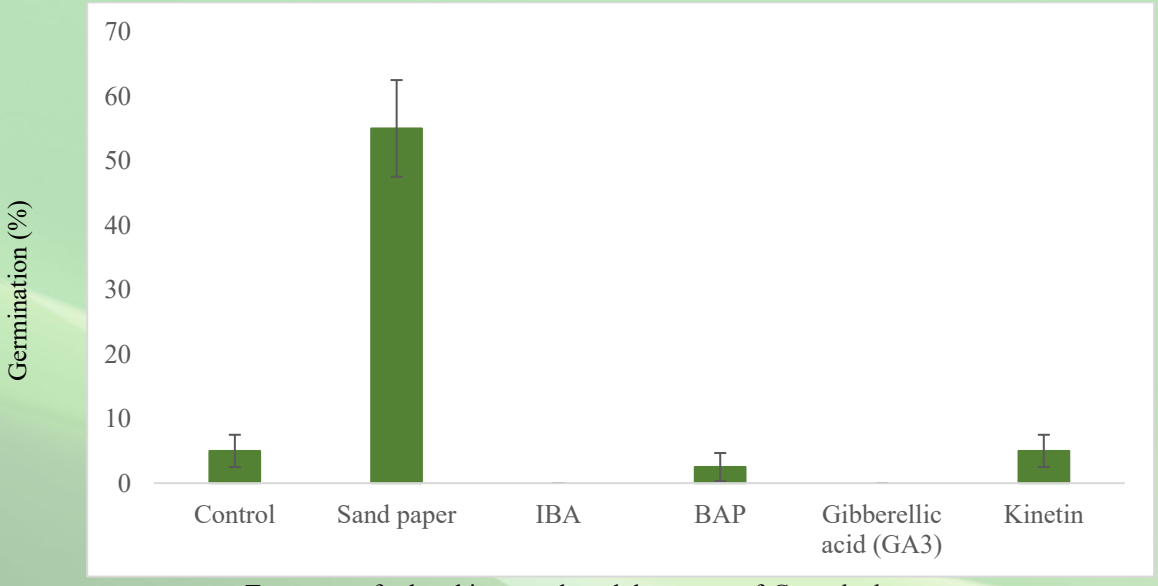
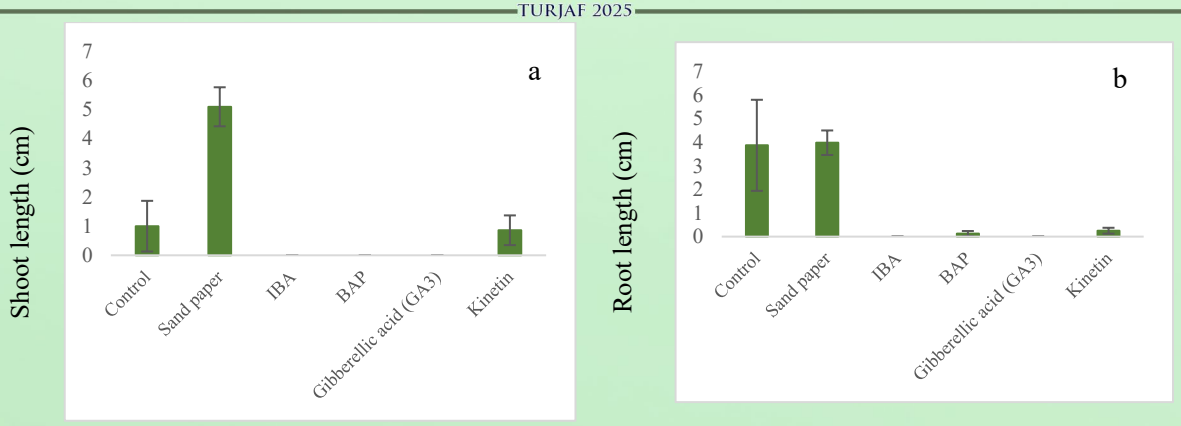


Fig. 1. Effect of different treatments on germination of *Convolvulus arvensis* seeds

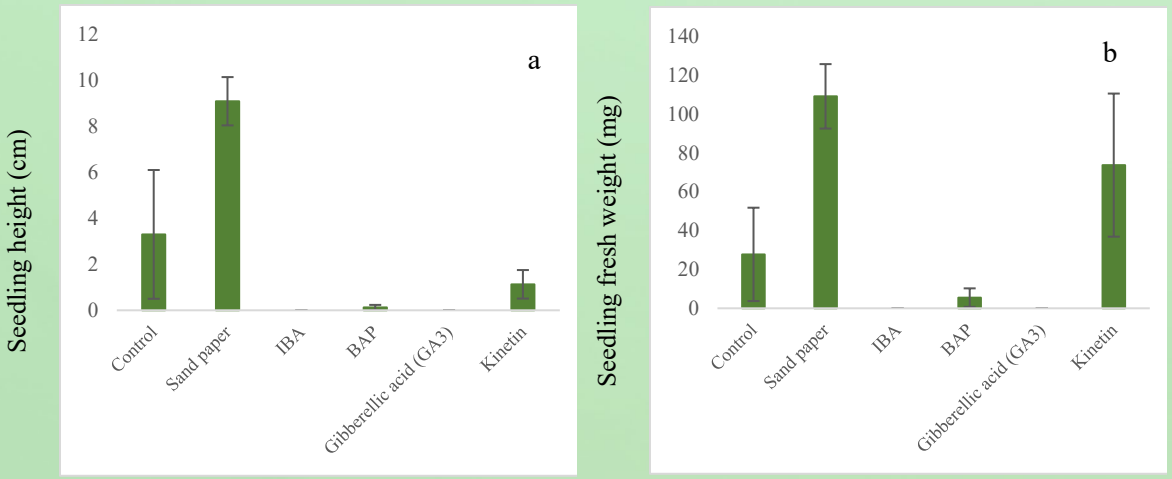
The highest shoot length was noted for the *C. arvensis* seedlings for which the seeds had been treated with sand paper (Figure 2a). The treatments including control and kinetin application were the only two other treatments where seedlings had developed some shoot, and the shoot length was statistically similar for thes two treatments. No shoot was observed in the weed seeds applied with IBA, BAP or gibberellic acid hormones. Both the control and scarification with sand paper had developed the longest root and the root length for these two treatments was statistically similar (Figure 2b). Kinetin and BAP applied weeds seeds had developed very short roots (< 1 cm).



Treatments for breaking weed seed dormancy of *Convolvulus arvensis*

Fig. 2. Effect of different treatments on germination of *Convolvulus arvensis* seeds

The longest seedlings were found for the *C. arvensis* seeds that were treated with sand paper followed by the control and kinetin (Figure 3a). The highest seedling fresh weight was recorded for the treatment where *C. arvensis* seeds for treated with sand paper followed by the seedling fresh weight with the kinetin treatment (Figure 3b).



Treatments for breaking weed seed dormancy of *Convolvulus arvensis*

Fig. 3. Effect of different treatments on germination of *Convolvulus arvensis* seeds

Discussion

In this study, scarification with sand paper was the most effective treatment in breaking the dormancy in *C. arvensis* while the different hormones proved to be ineffective. The most important reason for this may be the presence of hard seed coat in *C. arvensis* seed (Sosnoskie et al. 2020). The mechanical treatment with sand paper was able to damage the hard seed coat of the weed that ultimately lead imbibition of water and ease in the excahange of gases by the weed seeds (Rocha et al. 2022). As the imbibition of water is the first step in germination of viable plant seeds, damage to hard coat by sand paper helped water movement into the seed (Orozco-Segovia et al. 2007). Similarly, the damage to the seed coat is also expected to facilitate the exchange of gases. The effectivenss of the sand paper also imply that the type of dormancy in *C. arvensis* was primary and physical dormancy.

The hormonal treatments were ineffective in removing the dormancy from *C. arvensis* seeds that implies that the dormancy in these weed seeds was not because of hormonal imbalance (Shu et al. 2006) while the mechanical damage to the seed coat of *C. arvensis* can help in removal of dormancy in this weed. These results have implications for practical weed control under field conditions. This means that the *C. arvensis* seeds present in a field may be exposed natural or artificial factors so that their seed coat is damage. The damaged and weakened seed coat will lead to germination of the weed and the weed seeds will not become a part of soil weed seedbank.

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AI and IoT-Based Smart Irrigation: A Review of Challenges and Future Trends

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Abstract

Artificial Intelligence (AI) and Internet of Things (IoT) integration has established a new generation of intelligent irrigation systems that deliver sustainable water management solutions to address world water scarcity problems and agricultural requirements. This literature review presents an analysis of the present situation and obstacles alongside emerging trends of AI and IoT-based smart irrigation systems supported by international examples and technological milestones. Physical water conservation through AI-driven irrigation systems combined with IoT sensor surveillance and drone monitoring results in 20-35% water savings at the same time as improved yield outcomes across Australian regions together with Indian and Spanish territories. The wide use of smart irrigation systems is limited by technical difficulties that prevent rural Africa from connecting by economic pressures on poor farmers and by ethical challenges with European data security. The deployment become challenging because of scalability issues and maintenance problems that affect different farming ecosystems. The development of emerging technologies like edge computing, blockchain, and 5G, together with solar-powered IoT systems, provides solutions alongside research efforts toward energy-efficient climate-friendly designs. A comprehensive review combines current evidence into two major parts to evaluate its impacts on farmers, policymakers, and researchers. The review also shows where scalability and accessibility remain limited. The success of AI and IoT precision farming technology relies on cooperative work between multiple fields of study together with equal policies that support their implementation. Time must be dedicated to resolving these problems because smart irrigation systems need to fulfill worldwide food security along with sustainable development targets.

Key words: AI-driven irrigation, IoT sensors, smart agriculture, precision irrigation, water management, blockchain in agriculture, edge computing, renewable energy irrigation

1.1 Introduction

Agriculture stands as the foundational element of worldwide food security, although its operation suffers from major problems because of growing populations joined with climate shifts and evaporating freshwater availability. A 40% water deficit exists in the global water supply estimation for 2050, while irrigation utilizes about 70% of worldwide freshwater withdrawals. The standard irrigation techniques present difficulties because they neither successfully optimize agricultural production nor protect the environment efficiently. The combination of Artificial Intelligence (AI) systems operating with Internet of Things (IoT) devices makes up a revolutionary irrigation solution under the name of smart irrigation. Having IoT devices monitor environmental parameters gives AI systems the ability to manage water consumption efficiently and determine irrigation requirements and guide decision-making processes. This combined technology approach will direct farming operations into a new exacting direction which brings sustainable water management practices alongside higher agricultural output.

1.2 Objectives of the Review

The review examines existing knowledge about AI and IoT-based smart irrigation systems which focuses on their applications together with their limitations as well as future potential. This paper examines three essential aspects regarding AI and IoT applications in irrigation practices: (1) describes current integration methods, (2) describes key barriers affecting adoption, and (3) investigates emerging models for future smart irrigation systems. Through this combined technical and practical approach, this study provides essential information for researchers, practitioners and officials who work in agriculture technology fields.

1.3 Scope and Methodology

This review investigates AI and IoT applications in irrigation management while not addressing broader agricultural applications except when they directly touch irrigation systems. The review examines recent research from peer-reviewed journals, conference materials, and technical reports that originate mainly from IEEE Xplore, Scopus, and Google Scholar databases during the previous ten years. The search for relevant literature relied on the selected keywords “AI in irrigation,” “IoT smart irrigation,” “precision agriculture,” and “water management technologies.” The study included research papers about AI-IoT integration challenges and innovations and future direction works that maintained a focused relevant analysis. The analysis focuses on worldwide ideas that additionally respect geographical differences between various agricultural tech acceptance and farming requirements.

2. Overview of AI and IoT in Smart Irrigation

2.1 Core Concepts

Two major functions guide smart irrigation technology through the integration of Artificial Intelligence (AI) and the Internet of Things (IoT). These functions include the acquisition of data and the implementation of intelligent decision systems. IoT consists of networked objects including sensors that monitor ground moisture and weather monitoring systems and controllers which share information through wireless communication networks (Selvam & Al-Humairi, 2023). The established monitoring infrastructure tracks vital measurements including soil water levels together with environmental humidity and prediction of rain events. AI-operated algorithms consisting of ML and DL generate insights from the processed data (Rane, *et al.,* 2024). AI analyzes weather data in combination with plant water needs to establish ideal irrigation timing which leads to better water use efficiency and reduced wastage. The combination of these technologies operates in a self-contained system which dynamically responds to environmental changes thus making smart irrigation differ from conventional approaches.

2.2 Evolution of Smart Irrigation Systems

The techniques of irrigation have experienced drastic changes as human-operated flood irrigation systems evolved to technology-powered automated irrigation systems. The early development of irrigation technology integrated timer-based sprinklers and drip irrigation yet did not offer adjustable controls (Tripathi, 2022). The early development of IoT in the 2000s enabled farmers to use mobile device connectivity for monitoring sensors which helped them modify irrigation routines. Prediction technology and automation have brought AI systems into the current irrigation development. AI-IoT combines to minimize water consumption by 30% better than traditional techniques yet produces equal or better production results (Senoo *et al.,* 2024). Precision agriculture represents the dominant movement in which resource management becomes the most critical aspect.

2.3 Key Components

The functionality of AI and IoT-based smart irrigation systems depends on various hardware and software collaborative elements. Low-power IoT devices like capacitive soil moisture sensors and weather stations together with solenoid valves constitute hardware components (Shamsudeen, 2021). These devices operate on solar-powered batteries to maintain sustainability for distant locations. Cloud platforms collect IoT network data through software components where AI algorithms execute data analysis to create irrigation strategies beginning with basic regression models and ending with neural networks (Preite & Vignali, 2024). The components of an irrigation system use ZigBee and LoRaWAN and Wi-Fi communication protocols to transfer data effectively (Dhatterwal, *et al.,* 2024). The system's scalable design operates well due to reliable connections between its parts while ensuring software interoperability.

3. Current State of Research

3.1 Applications of AI and IoT in Irrigation

AI and IoT applications for smart irrigation systems are widely adopted by international agricultural sectors to suit various needs within different climate zones and economic ranges. The precision irrigation system serves as a primary use case that uses IoT devices with Artificial Intelligence algorithms for delivering precise water dispensations to targeted plant areas at correct times. This prevents irrigation water from going to waste. The adoption of these systems within Middle Eastern arid regions enables optimal date palm management through decreased water requirements by 25% according to (Alnaim *et al.,* 2022). The combination of IoT data from meteorological measurements with AI forecasting models enables water scheduling through weather-based methods which yields good results in Asian regions dependent on monsoons (Indira *et al.,* 2023). Soil and crop monitoring uses IoT multispectral sensors to collect data which machine learning processes for agricultural evaluation in both large-scale North American maize fields and Southeast Asian rice paddies (Solano Correa, 2025). The range of agricultural settings which proves the flexibility of AI-IoT solutions includes high-tech European commercial operations in addition to Sub-Saharan African areas with limited resources.

3.2 Notable Case Studies

Zone irrigation and collective irrigation programs benefit from real-world practices of AI and IoT technologies in irrigation management. The Murray-Darling Basin conducted an IoT and AI decision support system pilot project that cut water usage by 35% without affecting cotton production rates (Parr *et al.,* 2022). The Tamil Nadu Agricultural University in India built a low-cost IoT-AI system for drip irrigation and this technology enhanced rice production by 20% while attracting use from small farmer community (Ahmad & Nabi, 2021). AI enabled Spanish vineyards to increase their water efficiency rate by 30% through European Union backing for IoT data analysis (Linaza, et al., 2021). A Kenyan research study demonstrated limited water savings of 15% because of connectivity issues despite conducting the study in the region (Karuku, 2018). This showed discrepancies in local infrastructure development. The implementation examples demonstrate the capacity for and inconsistent advancement rates of smart irrigation systems worldwide.

3.3 Technological Advancements

AI together with IoT functionalities have received major enhancements in recent times. The development of sensor technology now includes affordable yet precise devices such as capacitive soil moisture sensors made by China

which are currently deployed across Asia and Africa (Aarif KO *et al.,* 2024)]. Deep learning models enable artificial intelligence to predict irrigation requirements precisely which is apparent through studies that used neural networks in Brazilian soybean fields (Baio *et al.,* 202)]. Large-scale monitoring became possible through the data fusion of IoT information and satellite images and drones particularly in Canada's prairie farming region (Sishodia *et al.,* 2020). Cloud-based platforms operating in Japan and Germany use mobile apps to allow real-time processing and connect farmers to database resources (Zhang, 2024). Smart irrigation technologies continue to advance worldwide due to local research communities who work across multiple continents.

4. Challenges in AI and IoT-Based Smart Irrigation

4.1 Technical Challenges

The implementation of AI and IoT technologies for smart irrigation systems encounters substantial technological challenges in different areas and infrastructure networks. Sensor-driven data accuracy represents a crucial problem because environmental elements including dust in North African deserts and tropical Southeast Asian moisture can compromise sensor performance (Gualtieri, *et al.,* 2024). The connectivity issue is a major problem in regions with limited internet access like Sub-Saharan Africa since the area suffers from poor cellular network coverage that disrupts IoT data transmission (Onsomu, *et al.,* 2024). The high demands for data processing capacity from AI models create operational problems for developing countries because they do not have strong computing infrastructure or cloud access (Rehan, 2024). Research conducted in India showed real-time processing delays decreased irrigation efficiency by 15% in regions restricted by limited resources according to available findings (Nsoh, *et al.,* 2024). The technical obstacles serve as evidence that flexible systems that work well for different worldwide environments need to be developed.

4.2 Economic and Adoption Barriers

The integration of AI-IoT irrigation systems faces scalability limitations because of economic obstacles and challenges with adoption mainly affecting low-income agricultural economic settings. Poorest communities especially struggle to afford investment costs in IoT hardware coupled with AI software that can reach thousands of dollars per unit of cultivated land (Hambye & Desmet, 2021). Government aid programs in Latin American regions struggle to promote AI-IoT irrigation systems adoption because both maintenance costs and technical illiteracy prevent rural area adoption (McCarthy, *et al.,* 2024). The survey conducted in Eastern Europe revealed that 60% of farmers showed ignorance regarding smart irrigation advantages as they maintained a preference for traditional irrigation practices (Ricart & Rico-Amorós, 2021). Wealthier regions with technical proficiency such as North America as well as Western Europe receive the majority of digital technology uptake because of economic and social factors that create a divide between communities.

4.3 Environmental and Ethical Concerns

AI and IoT irrigation systems produce environmental as well as ethical concerns in addition to technical and economic challenges. The energy usage of IoT devices and AI computing requires significant power consumption that leads to carbon emission problems identified as main sustainability concerns in Scandinavia (Ruilova Alfaro, 2024). Data privacy poses an ethical problem for EU farmers since they are worried IoT devices transmit their information to external organizations under GDPR (Ryan *et al.,* 2024). The implementation of technology has encroached upon traditional farming wisdom in indigenous areas across Australia and South America, causing concern about cultural heritage maintenance (Bellwood, 2022). A fair balance needs to be established that connects smart irrigation systems to worldwide sustainability and fairness goals.

4.4 Scalability and System Maintenance Challenges

The deployment of AI and IoT irrigation systems on a large scale after successful tests faces logistical obstacles that become more difficult due to required maintenance work. Scalability is restricted because agricultural systems with different landscape variations prevent systems from successfully being implemented across multiple agricultural areas (Salpina, 2020). The Chinese national smart irrigation program encountered interoperability problems between different provinces because its IoT protocols remained unstandardized (Zeng *et al.,* 2025). Adoption becomes more difficult because remote areas like rural Mongolia and the Andean highlands lack technical support, while sensors and devices need regular maintenance procedures (Orlove *et al.,* 2024). A South African examination uncovered that 40% of IoT irrigation systems stopped functioning after two years because of poor maintenance practices, which underlines the requirement for such systems to have durable life cycles and low-maintenance provisions (Alharbi *et al.,* 2024). Smart irrigation faces sustainability threats throughout its extended application because of various obstacles that specifically affect resource-constrained and diverse agricultural regions.

5. Future Trends and Innovations

5.1 Emerging Technologies and Innovations

Smart irrigation with AI and IoT deployed by the following technological advancements will increase the efficiency and global adaptation of this system. Implementing AI predictive models equipped with deep learning and machine learning functions enables precise water need forecasting to control irrigation timings. Brazilian

soybean automation through neural networks cut water consumption by 20% in a solution suitable for Southern African rural areas (Silva *et al.,* 2024). The use of UAVs (drones) in crop monitoring leads to better real-time detection, which helped Canadian prairie farmers increase their wheat production by 15% (Al-Mallahi, 2024) and Kenyan small-scale farmers map maize fields at a reasonable cost (Wanyama *et al.,* 2021). The Dutch track water use by blockchain technology, while edge computing reduces response time at remote agricultural locations in Central Asia. Technology developments in South Korea advance 5G for quick irrigation control (Watts *et al.,* 2019). The Netherlands, along with the U.S., participates in blockchain and edge computing for data processing efficiency and security (Ahmed *et al.,* 2024). Smart irrigation technology is moving toward worldwide adoption due to recent innovative developments.

5.2 Research Directions

Scientists will tackle existing issues in research by building upon these emerging trends. The implementation of solar-powered IoT systems with renewable energy systems stands as a primary research priority because they helped Spanish olive farms conserve 40 percent of their energy costs and Ethiopian smallholder farmers received an additional 50 percent irrigation capacity (Mérida García, 2020; Tesfaye *et al.,* 2021). Solar IoT implementations in Sub-Saharan Africa help to decrease the carbon emissions of these systems (Mukisa *et al.,* 2022). Research teams in Bangladesh are developing affordable AI-Internet of Things kits that aim to give small farmers the power they need (Satapathy *et al.,* 2022), and AI software from Brazil predicts drought timing patterns compatible with Southern Africa (Chivangulula *et al.,* 2024). Through collaboration between agronomists and data scientists in Japan and Canada, researchers have found comprehensive answers (Suresh *et al.,* 2024). The established directions work to establish both sustainability and access to smart irrigation throughout agricultural locations with varied environments.

5.3 Policy and Industry Implications

The complete implementation of these innovations depends on strong support from both government policies and industrial organizations. Governments should provide financial support for solar-IoT systems. The German public-private partnerships build farmer-friendly platforms that serve as a model for European territories (Sjaf *et al.,* 2022). The adoption rate of drones and blockchain in industries continues to grow because Mexico established farmer training programs for UAV operation and IEEE developed universal IoT standards for Southeast Asia (Tiwari *et al.,* 2021; Wangere, 2024). International joint investments in AI and renewable energy research development are speeding up deployment worldwide through Chinese edge-blockchain pilot programs (Yang *et al.,* 2025). These initiatives guarantee that technology breakthroughs become practical benefits that reach all farmers justly across the board.

6. Discussion

6.1 Synthesis of Findings

Smart irrigation has experienced a revolutionary change because of AI and IoT implementation that has been proven through multiple case studies and research developments. Through the combination of IoT sensors with AI analytics systems and precision irrigation methods, water savings reached between 20-35% in Australian, Indian, and Spanish locations (Wei *et al.,* 2024) while drone-based farming and predictive analysis techniques improved agricultural productivity in North American and African territories (Guebsi & El Wai 2025). Several roadblocks, mainly stemming from technical difficulties regarding rural African internet connectivity combined with economic factors influencing Asian smallholders and European privacy rights, are preventing the widespread adoption of the proposals. The integration of solar-powered systems in Ethiopia, combined with blockchain solutions in the Netherlands, provides a solution for existing barriers, but China faces difficulties in achieving standardization following their deployment (Abiri *et al.,* 2023; Polymeni *et al.,* 2024). This work highlights two conflicting trends that show major potential restricted by continuing obstacles that affect different regions and resource amounts.

6.2 Implications for Stakeholders

The results deliver significant ramifications that affect stakeholders all over the world. The implementation of AI-IoT technology provides efficiency improvements to farmers yet necessitates affordable user-friendly solutions, which are vital for South Asian and Latin American small-scale farmers (Muhammed *et al.,* 2024). Water-scarce nations such as Morocco need policymakers to establish both training programs and financial aid schemes, which have proven successful in Israel (Tinazzi, 2024). The refinement of scalable and energy-efficient technologies requires research collaboration across different fields of study similar to Canadian research institutions (Neethirajan, 2024). The adoption of new agricultural technologies, such as edge computing in remote Central Asian regions, can be achieved through industry collaborations led by drone manufacturers and IoT developers, much like in Germany and by extending to Central Asian farms. The stakeholders must work together toward producing effective transformational outcomes from research through efforts that suit different agricultural settings.

6.3 Limitations of the Review

The review aims to be comprehensive; however, some restrictions need to be acknowledged. The majority of studies in English-language publications bias researchers against evaluating important research conducted in

Spanish or Chinese, which could hide valuable innovations from Latin America and East Asia. The examination of recent research during the last decade fails to include fundamental studies that established the framework for smart irrigation development. Successful case studies dominate the research due to published limitations since resource-limited areas, particularly Sub-Saharan Africa, often fail to report their unsuccessful implementations (Higginbottom et al., 2021). Further research should expand linguistic and geographical bounds in reviews to achieve full global representation of research.

Conclusion

Artificial Intelligence (AI) integration with the Internet of Things (IoT) brings substantial opportunities for global water shortage management and increased agricultural crop outputs. Predictive AI models and IoT monitoring, along with drone application, blockchain technology, and solar-powered systems, prove effective in water utilization optimization and increased yield production throughout Australia to Ethiopia. The extensive implementation faces multiple obstacles that include technical obstacles as well as financial hurdles and scalability problems and ethical issues which predominantly impact regions such as Sub-Saharan Africa and South Asia which have limited resources. The implementation of edge computing with 5G technology and renewable energy integration requires major combined work to achieve their future applications.

Technology in precision agriculture earns its value because it generates sustainable farming systems through precise management capabilities. Implementing these methodologies demands the elimination of the digital gap through affordable technology systems that support robust policies across the board. The authors propose that researchers should conduct more studies about energy-efficient, affordable agricultural system designs while improving collaborative work between agronomists and engineers along with policymakers. People across the world in agricultural roles alongside governmental organizations, scientific researchers, and industrial experts should join forces to lead this technology adoption. AI and IoT-based smart irrigation represent a vital opportunity in the present climate to protect both our food supply and environmental systems because water availability continues to decrease.

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ID: 591

Mapping the Genetic Structure in Chicken Genomes Using SNP Chips: Perspectives on Conservation and Breeding

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Abstract

Rapidly increasing global human population has significantly raised the demand for high-quality and sustainable protein sources. In this context, chicken meat has a strategic importance in human nutrition due to its economic production efficiency, high nutritional value, and low environmental footprint. It is anticipated that meeting future protein requirements will largely depend on enhancing productivity and adopting sustainable poultry production systems. Therefore, accurately revealing the genetic potential of local chicken breeds is crucial, not only for increasing productivity but also for maintaining biological diversity. Understanding genetic structure and diversity among chicken breeds is essential for sustainable animal breeding programs and the conservation of local genetic resources. Recently, high-density Single Nucleotide Polymorphism (SNP) chip technologies have emerged as powerful tools for investigating genetic characteristics in chickens. This technology enables simultaneous analysis of thousands of SNPs, facilitating accurate and precise assessments of population structure, inbreeding levels, heterozygosity rates, and genetic differentiation indices (FST). Different SNP chip densities (e.g., 5K, 10K, 50K, and 100K SNP) are available, and their selection depends primarily on research objectives, genetic composition of populations, and budget considerations. These SNP chips offer a broad spectrum of applications, ranging from basic genetic diversity analyses to genome-wide association studies (GWAS). This review focuses on genetic analyses conducted in chickens using SNP chip technology and comprehensively evaluates current literature on comparative genomic profiling of local and commercial breeds. Additionally, it addresses methodological approaches, advantages, and limitations associated with widely-used commercial SNP chips, such as those provided by Illumina and Affymetrix. The strategic role of SNP data in identifying selection signatures, mapping homozygous a critical component not only at the molecular level but also in applied animal breeding policies.

Key Words: *SNP chip, Chicken genomics, Genetic diversity, Phylogenetics, Conservation of genetic resources*

Tavuk Genomiğinde SNP Chip Kullanımı ile Genetik Yapının Haritalanması: Koruma ve Islah Perspektifi

Özet

Küresel ölçekte insan nüfusunun hızla artması, kaliteli ve sürdürülebilir protein kaynaklarına olan talebin giderek yükselmesine neden olmaktadır. Bu bağlamda tavuk eti, ekonomik üretim avantajları, yüksek besin değeri ve düşük çevresel ayak izi ile insan beslenmesinde stratejik bir konuma sahiptir. Gelecekte beklenen protein ihtiyacının karşılanması ise tavuk üretiminde verimliliğin artırılması ve sürdürülebilir üretim modellerinin benimsenmesi ile mümkün olması düşünülmektedir. Bu nedenle, yerli tavuk ırklarının genetik potansiyelinin etkin bir biçimde ortaya çıkarılması, hem verimlilik artışı sağlanması hem de biyolojik çeşitliliğin korunması açısından büyük önem taşımaktadır. Tavuk ırklarının genetik yapılarını ve çeşitliliklerini anlamak, sürdürülebilir hayvan ıslahı programları ve yerel genetik kaynakların korunması için elzemdir. Son yıllarda, tavuklarda genetik yapının ortaya çıkarılmasında yüksek yoğunluklu tek nükleotid polimorfizm (SNP) chip teknolojileri güçlü bir araç olarak öne çıkmaktadır. Bu teknoloji, binlerce SNP eş zamanlı olarak analiz ederek, populasyon yapısı, inbreeding düzeyleri, heterozigotluk oranları ve genetik farklılaşma indeksi (FST) gibi parametrelerin güvenilir ve hassas biçimde belirlenmesini mümkün kılmaktadır. SNP chip teknolojisinde farklı yoğunluklardaki SNP chip (5K-10K-50K-100K) kullanılmakta olup, chip yoğunluklarının seçiminde çalışma amaçları, popülasyonların genetik yapısı ve araştırmanın bütçesi gibi kriterler belirleyici olmaktadır. Farklı yoğunluktaki SNP chip, temel genetik çeşitlilik analizlerinden genom çapında ilişkilendirme (GWAS) çalışmalarına kadar geniş bir uygulama alanı sunmaktadır. Bu derleme çalışması, tavuklarda SNP chip teknolojisiyle gerçekleştirilen genetik analizlere odaklanarak, yerli ve ticari ırkların genomik yapılarını karşılaştırmalı olarak değerlendiren güncel literatürü incelemektedir. Ayrıca Illumina ve Affymetrix gibi yaygın kullanılan ticari SNP chip avantajları, sınırlılıkları ve veri analizinde kullanılan metodolojik yaklaşımlar kapsamlı şekilde ele alınmaktadır. Seleksiyon kriterlerinin belirlenmesi, homozigot bölgelerin haritalanması ve koruma genetiği uygulamalarında SNP verilerinin stratejik rolüne dikkat çekilmekte, SNP chip teknolojisinin moleküler düzeyin yanı sıra uygulamalı hayvancılık politikaları açısından da kritik bir bileşen olduğu vurgulanmaktadır.

Anahtar Kelimeler: *SNP chip, Tavuk genomiği, genetik çeşitlilik, filogenetik, Genetik kaynakların korunması*

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Adoption of Good Agricultural Practices (GAP) by Vegetable Farmers for Safe Food: An Empirical Study on Dinajpur District

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Abstract
In order to produce safe and healthy food and agricultural products, Good Agricultural Practices (GAPs) are a set of guidelines that should be followed during the production process on farms as well as during post-production, all the while considering the sustainability of the economy, society, and environment. Therefore, the research focus was to determine the extent of awareness and adoption of Good Agricultural Practices (GAPs). A mixed method was followed during conducting the study. A sample of 120 vegetable farmers were selected by following simple random sampling technique and by following proper sampling formula. Data were collected by a pre-tested interview schedule during 01 January to 31 May 2024 by face-to-face interview method. Descriptive statistics as well as inferential statistics like Pearson Product Moment Correlation Coefficient analysis were followed. Findings reveals that more than half of the respondents (56.7%) had medium awareness level on GAP while majority (65.0%) of the vegetable farmers had low level of adoption of Good Agricultural Practices in vegetable cultivation. Factors such as area under cultivation, experience, training received, market perception, environmental orientation, and extension contact demonstrated a positive and significant relationship, underscoring the importance of these elements in enhancing GAP adoption among farmers. The most important constraint is increased difficulty in management of pest and disease incidence having mean score of 2.7.

Key Words: GAP, Adoption, Vegetable farmer and Safe food

Introduction

In Bangladesh, agricultural sector is gradually changing from subsistence agriculture to commercial agriculture. In view of producing more food as well as increasing crops production for growing population, high yielding and hybrid varieties of crops are being used with excessive chemical fertilizers and pesticides. Sometimes organic fertilizer that contained heavy metals or chemicals harmful to human health are also used. Good Agricultural Practices (GAPs) addresses the environmental, economic and social sustainability issues for safe and quality food and non-food agricultural products like vegetables.

The demand for quality and safety in vegetables has led to the development and promotion of common principle and standards for cultivation, often referred to as Good Agricultural Practices (GAP) (Guddanti, 2015). Considering the availability of safe food, it is very important to follow Good Agricultural Practices (GAP) from the beginning of production, harvest and post-harvest processing, such as collection from field, packaging, transportation etc. to ensure safe food. The GAP is a set of principles that apply to the farm production and post-production processes to produce safe and healthy food and non-food agriculture products, considering economic, social, and environmental sustainability (Hobbs, 2003). Adoption of GAP could increase farm income by 6.2% and decrease the use of synthetic fertilizers by 31% for rice, lentil, tomato, and ginger in Nepal (Bairagi et al., 2019). Many developed countries, such as Denmark, Australia, and the United States have adopted the GAP package for integrated pest and nutrient management for decades (Waage ,1998; Zalucki et al., 2009; Remac, 2018). In Turkey, GAP has been implemented as an alternative to organic farming (Akkaya et al., 2005). Also in several Asian countries such as Nepal, India, Indonesia, Malaysia, Philippines, and Thailand, the GAP system has been implemented particularly in vegetable farming, focusing more on integrated pest and soil fertility management. GAP use is practical in wide categories of farming system of different scales through improved sustainability by integrated pest, weed and disease management, soil and water conservation, and fertilizer management (Ntshangase et al., 2018). Good Agricultural Practices are desirable increased productivity and improved quality (Dudeja and Singh, 2018).

Safe food is becoming increasingly important in terms of human health and economic aspects. Safe food production is urgent because of the competition in the global export market, as well as protecting people from food bound illness. Indiscriminate use of pesticides and chemical, presence of heavy metals, infection s of microorganism etc. from the early stages of production to various stages of food chain made food unsafe. That is why, considering the availability of safe food, it is very important to adopt Good Agricultural Practices (GAPs) from the beginning of production, harvest, and post-harvest processing such as collection from field, packaging,

transportation etc. to ensure safe food. In Bangladesh especially in the proposed study areas if the adoption of GAPs is ensured, then the vegetable produce will be safe, improved and of good quality, sustainable environment and social acceptance will be increased with income growth and economic momentum, and food and nutrition security will be ensured.

Therefore, it is really very necessary to adopt GAP for the production of vegetable for ensuring the quality of vegetable to export. Good Agricultural Practices (GAP) minimize food safety risk. However, its poor implementation along the vegetable production chain is a challenge. GAP, if carefully implemented ensures that farmers can obtain highly nutritional, good quality vegetables with higher market access. Well-managed GAPs have proven to be effective in the reduction of risks of vegetable contamination in agricultural production.

Therefore, it is necessary to have a clear understanding of the present status of the adoption of Good Agricultural Practices. The main purpose of the study is to have an understanding of the adoption of Good Agricultural Practices by the vegetable farmers in vegetable cultivation.

The proposed research study is designed by considering the following framed out specific objectives:

i) To determine the extent of awareness on Good Agricultural Practices (GAPs) in vegetable cultivation among the farmers.

ii) To assess the extent of adoption of Good Agricultural Practices (GAPs) by the vegetable farmers.

iii) To explore the relationship of the selected characteristics of the vegetable farmers on the adoption of Good Agricultural Practices (GAPs).

iv) To identify the confronted constraints of the vegetable farmers while implementing the Good Agricultural Practices (GAPs) in their field.

Review of Literature

Kharel et al. (2023) revealed that farmers were adopting different GAP, such as cropping practices, livestock integration, soil fertility management practices, and integrated pest management practices. Upon adopting these practices, farmers reduced agrochemicals' use by more than 40%. The critical incentives for surveyed farmers to adopt GAP were soil health improvement, farmers' safety, and reduction in the use of agrochemicals while improving the farm's image. Sunny et al. (2022) revealed that farmers' age, land typology, soil water retention, knowledge, and availability of cow dung significantly influenced Boro rice farmers' adoption decisions of recommended fertilizer doses. Chaudhary (2022) revealed that more than one half (57.50%) of the farmers were having medium adoption of good agricultural practices. Cherotich (2021) reported that a majority of the vegetable growers were unaware of GAP standards for vegetable production, with many deviating from the expected standards in their vegetable production activities. Most of the vegetable growers identified production costs, market exclusivity, training, government support, and access to labor as the key determinants to the use of GAP in their activities. It is also revealed that behavioural intention to adopt GAP by vegetable growers is predicted by attitude, subjective norms, and perceived behavioural control. Nagadevi (2021) explored that overall adoption index of GAP in vegetable cultivation was found to be medium (73.21). The adoption score on components of GAP viz. land preparation and soil management (79.56) and harvesting and post-harvest handling (81.05) was high, while that on seed quality parameters, sowing and intercultural operations, nutrient management and plant protection measures were medium. The component that had lowest level of adoption score was irrigation management and drainage (54.04). Thenuwara and Malknthi (2020) explored that most vegetable farmers in the Galle district have a general level of awareness on GAP and a positive attitude towards the GAP programme. However, most farmers do not adopt the GAP, and some farmers lack the required amount of information, technical know-how, inputs, capital, labour and require field conditions to practice GAP, even though thy wish to practice it. According to the results, awareness of GAP, GAP certification, and the awareness of the importance and benefits of GAP were the significant factors affecting the adoption of GAP by vegetable farmers. Joshi et al. (2020) revealed that GAP related to soil management and fertilization (87.4%) and harvesting and on-farm processing (94.2%) is adopted at a low level. Laosutsan et al. (2019) identified and investigated the factors influencing the adoption of good agricultural practices (GAP) and revealed that the income variable is the most influential factor in the GAP adoption by participating vegetable farmers. They also found that effectively increase the GAP adoption rate among the Thai vegetable growers, the exporters and relevant government agencies could make GAP certification compulsory. Pandit et al. (2017) revealed that awareness and the adoption of the critical GAPs in basmati production system was at lowest ebb, whereas the benefits of adoption were well understood by the farmers. Awareness level of farmers about Good Agricultural Practices in basmati rice was found to be 58.33%, whereas adoption was only 27.41% which is even less than half of awareness level. Srisopaporn et al. (2015) revealed that adoption and dis-adoption are highly related to household labour constraints, land ownership, and initial high expectations regarding the market opportunities of the GAP produced rice. They found several encouraging differences between non-adopters and first-time adopters, indicating better pest and nutrient management. Although they observed an important rate of dis-adoption, they also determined that farmers are maintaining those better practices even after abandoning the program. Banzon et al. (2013) revealed that a high level of GAP adoption in the Davao banana industry primarily because of the predominance of corporate farms in

the area that cater to the export markets. Athipanyakul and Pak-Uthai (2012) revealed that significant effect on program participation and farmer's knowledge that was the precursor of adoption. Farmers' experience in chili production significantly affected adoption. Age was a negative determinant of adoption. Adoption of knowledge-intensive technologies such as GAP needs an effective approach such as the participatory research program, which can improve farmers' knowledge and encourage them to adopt innovative technologies

Methodology

A mixed-method approach, combining quantitative and qualitative methods was adopted for the study, which includes farmers' surveys, key informant interviews, and in-depth interviews (Kharel et al., 2023).

Locale of the study

The proposed research study was conducted at the two upazilas namely Birol and Birganj under Dinajpur district as in these areas a plenty of vegetables are cultivated which is not only fulfil the local market demand but also export in the abroad. The proposed study areas are given in the Figure 1.

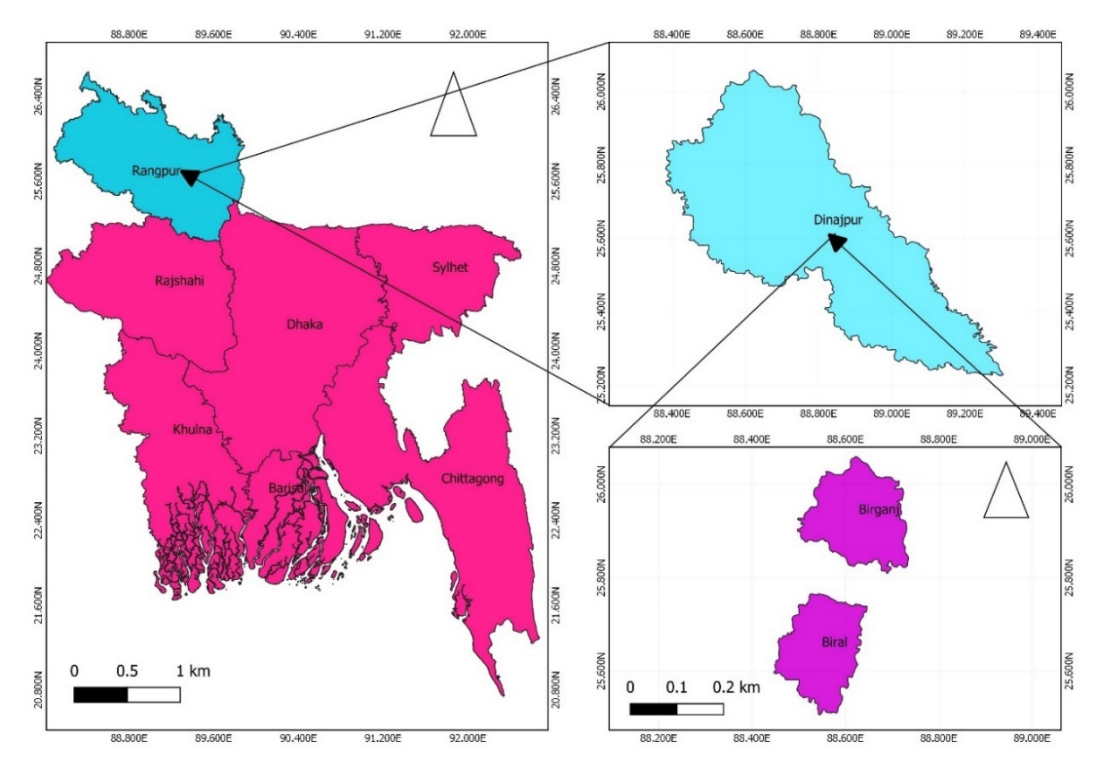


Figure 1. Map of the proposed study areas (prepared by using QGIS software)

Description of the study areas

Dinajpur is a district in the Rangpur Division of northern Bangladesh. It is the largest district among all sixteen northern districts of Bangladesh. Total area 3437.98 km^2, located in between 25°10' and 26°04' north latitudes and in between 88°23' and 89°18' east longitudes. Dinajpur experiences a hot, wet and humid tropical climate. Under the Koppen climate classification, Dinajpur has a tropical wet and dry climate. The district has a distinct monsoonal season, with an annual average temperature of 25 °C (77 °F) and monthly means varying between 18 °C (64 °F) in January and 29 °C (84 °F) in August. The economy of Dinajpur mainly depends upon agriculture-based production. There is a well-known proverb about Dinajpur – 'paddy piled up high, sheds full of cows, ponds brimming with fish' [*gola bhora dhan, goyal bhora goru, pukur bhora mach*]. People in this district are much happier than those in other districts, everything grows easily, it's a peaceful place. It grows a plenty of vegetables and seasonal fruits. Crops and grown in the district include rice, wheat, maize, potato, brinjal, and tomato.

Population and sampling

Vegetable farmers of the proposed study areas was the population of the study. An appropriate sample and reserve list was determined to avoid the uncertainty related with the availability of samples during data collection. Considering the study is intending to have statistically significant and comparable set of results for the study areas, sample size for the research was calculated using the following formula (Kothari, 2004):

$$n = \frac{Z2PQN}{(n-1)e2 + z2pq}$$

Where,
n= Sample size
Z= 1 the value of the standard normal variable at the chosen (95 percent) confidence level (1.96)
P= Probability (assume 0.5)
Q = Remaining from probability (1-P)
N = Total population
e = the level of precision (5 percent)

By using the above formula, the sample size of 120 vegetable farmers was found from a population list of 175, 60 from each selected upazila Birol and Birganj was selected by following simple random sampling techniques, respectively. Beside this, a reserved list of 12 farmers was prepared who were supposed to be interviewed only when a respondent in the original sample list was unavailable during data collection.

Measurement technique of the variables

The personal and socio-economic characteristics was selected by reviewing the relevant documents related to the present study and proper statistical techniques was followed to measure them.

Adoption of improved vegetable cultivation practices by the vegetable farmers was the focus issue of this research study. It was measured by using five-point rating scale. The respondents was requested to make response on their adoption of GAP related to vegetable cultivation. The score of the five-point rating scale against each of the GAP was given as follows:

Extent of adoption	Score assigned
Regularly (≥ 4 times in last 4 years)	4
Frequently (3 times in last 4 years)	3
Occasionally (2 times in last 4 years)	2
Rarely (1 times in last 4 years)	1
Not at all (0 times in last 4 years)	0

Based on the possible score range the respondents of the study was categorized as 'Low adoption', 'Medium adoption' and 'High adoption'. Similar measurement technique was followed by (Mou, 2015).

Adoption score= Score obtained by the vegetable farmers/Maximum possible score× 100

Awareness of GAP in vegetable cultivation will be operationalized as the information available to the vegetable growers about GAP in vegetable cultivation. To determine awareness, an audit checklist will be developed with reference to FAO, bgGAP recommendations, which captured farmers' awareness and compliance to GAP standards.

Awareness was measured through rating on a 3- point rating scale ranging from 2 for 'fully aware', 1 for 'partially aware', and 0 for 'not aware' developed by (Cherotich and Kaur, 2021). The respondents was categorized into the following three categories as none, partial, and full based on their observed score. Awareness score was calculated by using the following formula:

Awareness score= Score obtained by the farmers/Maximum possible score× 100

Confronted constraints of the vegetable farmers while implementing the GAP in their field level was measured by asking the question to the sampled farmer. In this regard, farmers were asked to assess how difficult it was for them to adopt good agricultural practices on a three-point scale of most serious, serious and least serious, with weights 3, 2 and 1 was assigned to each response.

Data collection techniques

Both quantitative and qualitative techniques was used for this research study. The flow chart of the data collection technique was followed as given below:

Preparation and administration of data collection tools

Data collection tool is a device which is used to collect the data. The interview schedule and checklist was developed on various aspects of the objectives considered in the present study. An interview schedule was prepared to collect quantitative data, while a checklist was prepared used in eliciting qualitative data through Focus Group Discussions (FGDs). Experts was employed to improve the content validity of the interview schedule and checklists for qualitative data collection. Reliability of the tools was also tested by Cronbach's alpha. Prior to the actual conduct of research, both the interview schedule and the checklist was pre-tested in similar socio-economic condition.

Statistical method employed for data analysis

Statistical analysis of quantitative data is an important aspect of research work, as it facilitates the condensation and interpretation of collected data in simple form helps in predicting future trends, helps in establishing relationship between different variables and provides sound base of policy formulation. After data collection, the data was input concerned SPSS 25.0 version data analyzing software. Then the normality of the data was tested and if any outlier present was removed. Data was analyzed in the light of the objectives set forth for the proposed study. Different types of statistical techniques like frequency, percentage, mean, standard deviation, ranking,

coefficient of correlation, was used for data analysis. The qualitative information and quantitative data analysis was performed separately, and their findings was synthesized for triangulation.

Data analysis plan

The collected data was analyzed using computer software like SPSS 25.0 version. The primary unit of analysis of the study was individuals, with results summarized for the study areas.

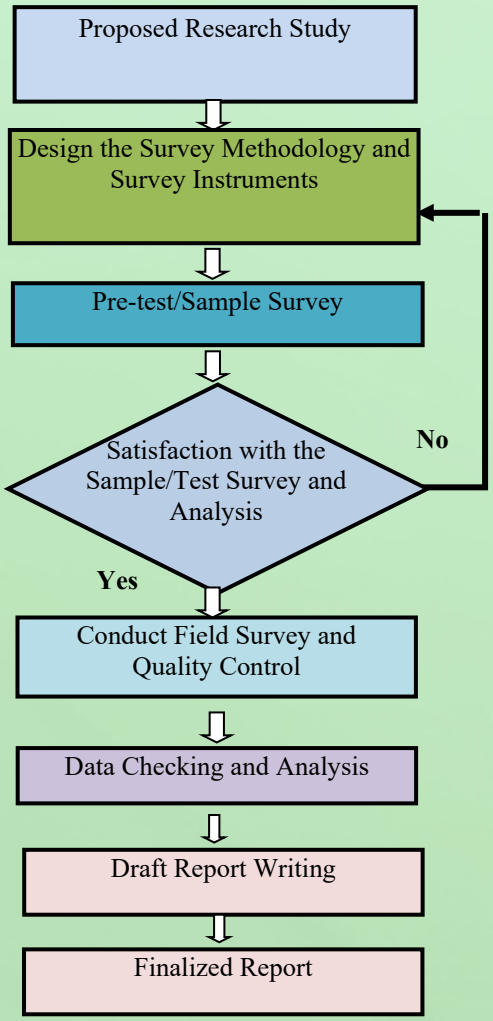


Figure 2. Flow chart for data collection

Results and Discussion

Selected characteristics of the respondents

Age

The age group of the vegetable farmers of the study areas included in the present study is given in Figure 3. It could be observed that more than half (58.3%) of the farmers fall under middle aged group of 36 to 50 years followed by exactly one-fourths of the respondents (25.0%) belonging to young aged category and only 16.7% of the vegetable farmers belong to the old aged category of above 50 years.

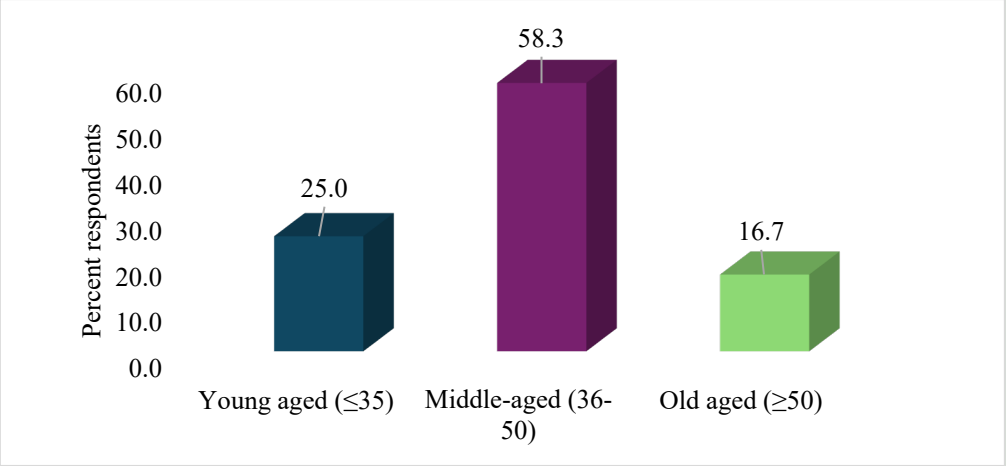


Figure 3. Distribution of the respondents according to their age

This indicates that all the age groups of the farmers were engaged in vegetable cultivation in the study areas. The results are found to be in tune with the natural trend of majority of the farmers under young to middle aged category as young are getting engaged in agricultural entrepreneurships.

Education

Educational qualification is regarded as an instrument of change and transformation of society. Education can be seen in the emancipation of women from the patriarchal society.

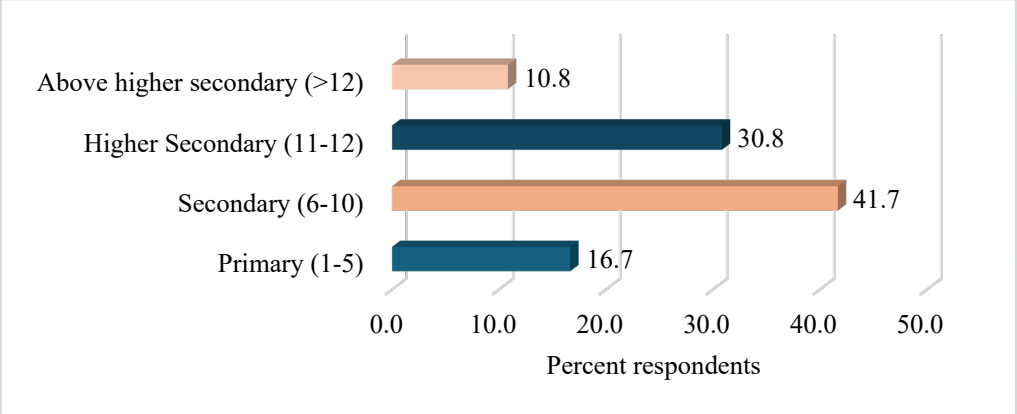


Figure 4. Distribution of the respondents according to their education

Findings presented in the Figure 4 show that majority (41.7%) of the farmers fall under secondary education category followed by one-third of the respondents (30.8%) belonging to higher secondary category, 16.7% of the vegetable farmers belong to the primary education category and only 10.8% are educated above higher secondary.

4.1.3 Area under vegetable cultivation

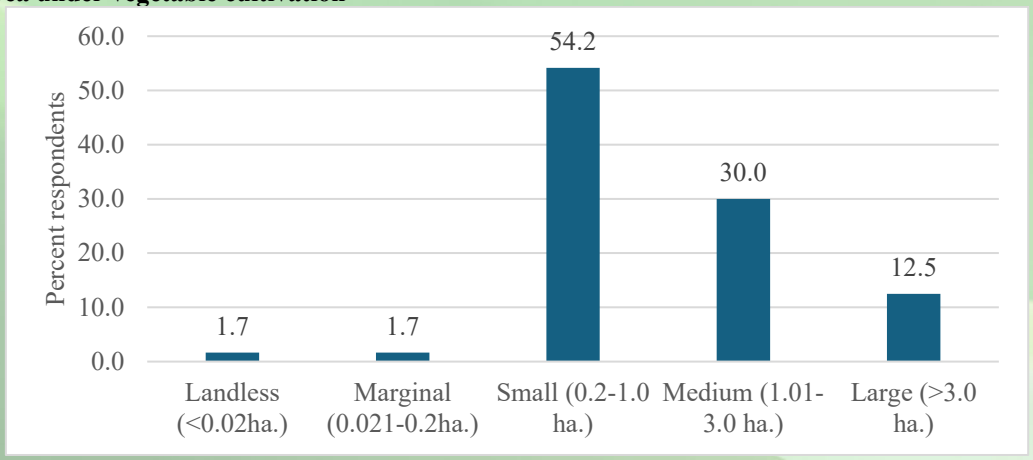


Figure 5. Distribution of the respondents according to their area under vegetable cultivation

The analyzed data in Figure 5 shows the distribution of vegetable farmers based on the area under vegetable cultivation. The categorization as made with five categories of landholding size (hectare) under vegetable cultivation. It is evident from Figure 5 that just more than half (54.2%) of the vegetable farmers fell under the group of land holdings 0.2 to 1.0 ha. whereas 30% of the farmers fell under the group of landholdings 1.01 to 3.0 ha, 12.5% fell under large land holding while only a negligible portion of the farmers i.e. 1.7% equally fell under landless and marginal landholding categories respectively.

4.1.4 Experience in vegetable cultivation

The vegetable farmers were grouped into three categories based on their experience in vegetable cultivation as given in Figure 6. The majority of the farmers (54%) had more than six years of experience in vegetable cultivation. Exactly one-fourths (25%) of the respondents had experience of 5-6 years while only 21% had experience of up to 4 years. The probable reason of the findings might be that the major crops cultivated in the study areas are vegetable.

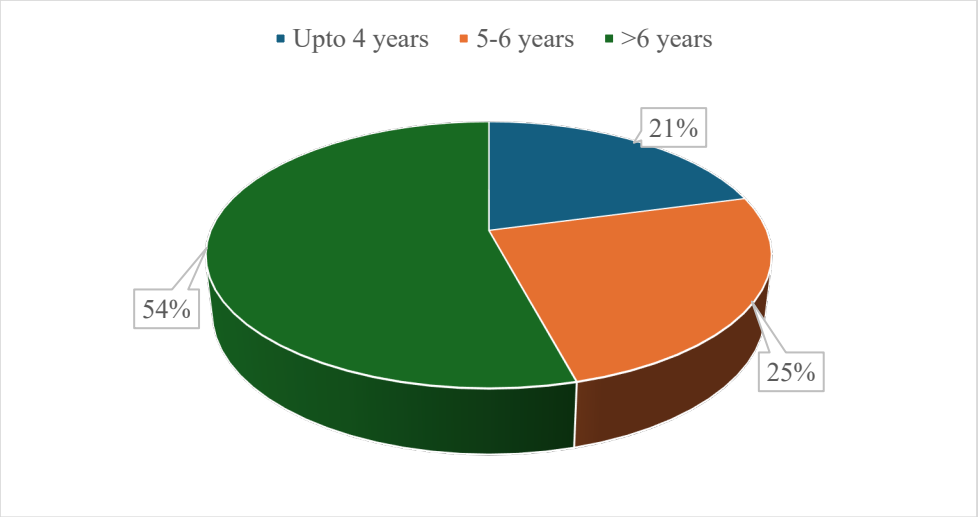


Figure 6. Distribution of the respondents according to their experience in vegetable cultivation

Training received

The expertise of an individual is enhanced by training and improves their skills, knowledge, and even attitude. Based on training received on, the vegetable farmers have been categorized as shown in Table 1.

Table 1. Distribution of the respondents according to their training received

Categories (Days)	Percent respondents
Low (1-2 days)	79.2
Medium (3-4 days)	12.5
High (>4 days)	8.3
Total=	100.0

More than three-fourths (79.2%) of the vegetable farmers were fell under low training received category followed by only 12.5 percent fell under the training received category of 3 to 4 days while only a vey negligible portion of the farmers i.e. 8.3% fell under high training received category i.e. more than four days.

Annual income

In a society individual levels of status determine by different factors, among them money is the most powerful, influential, and potential component. It is well known that the higher is the income of a family, the greater control over the society by the family. Family annual income is an important variable for explaining the economic characteristics of vegetable farmers.

Findings presented in the Figure 7 shows that more than half (58.3%) of the vegetable farmers fall under medium income category followed by exactly one-fourths of the respondents (25.0%) belonging to low-income category, 16.7% of the vegetable farmers belong to the high-income category.

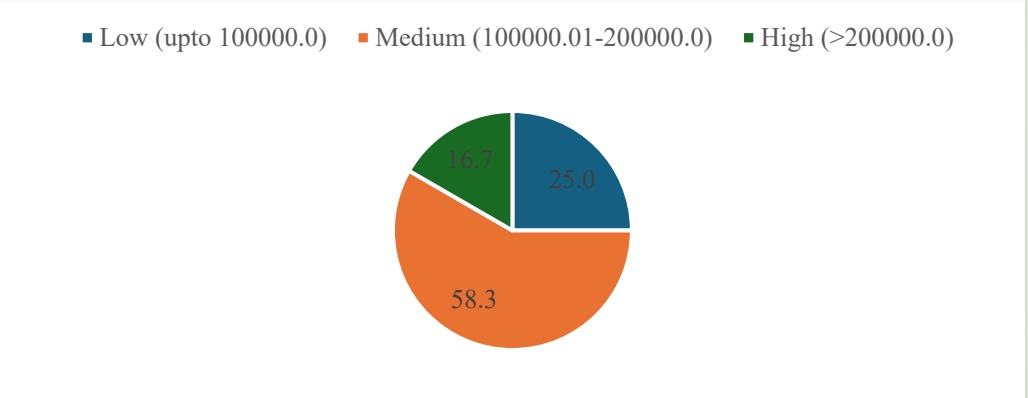


Figure 7. Distribution of the respondents according to their annual income

Market perception

The result in Figure 8 showed that the distribution of the vegetable farmers based on their market perception. It could be observed that about half (49.2%) of the farmers had medium level of market perception followed by just more than one-third (34.1%) of the respondent had low market perception and only 16.7 percent of the vegetable farmers had high level of market perception.

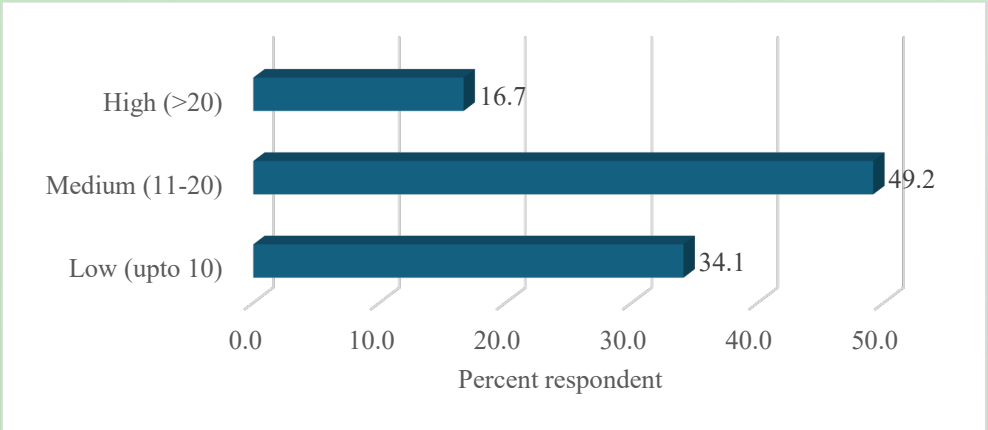


Figure 8. Distribution of the respondents according to their market perception

The possible reason for this finding might be that the vegetable farmers are more concerned about the market opportunities available for vegetables and the possibility to get remunerative price for GAP vegetables.

Environmental orientation

It could be inferred from the result in Figure 9 that exactly half (50.0%) of the respondents had low level of environmental orientation followed by 32.5% of them had medium and only 17.5 percent of the respondent had a low level of environmental orientation.

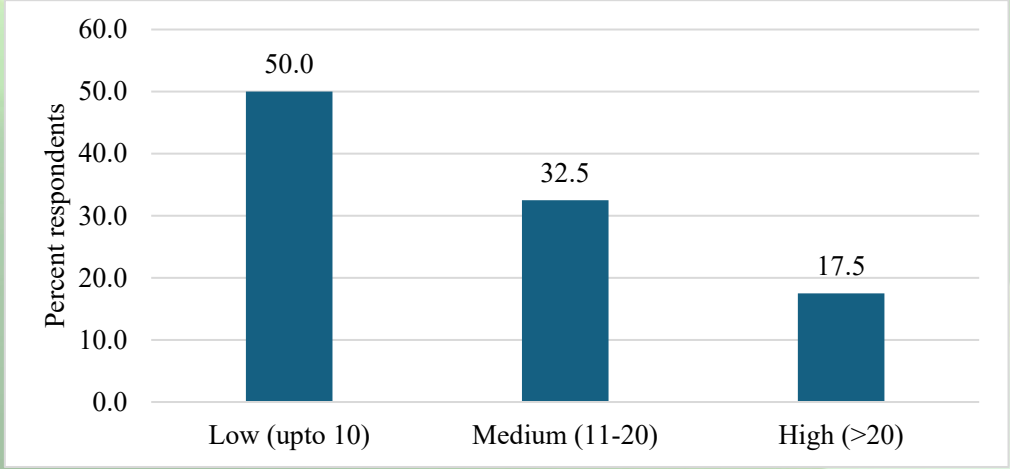


Figure 9. Distribution of the respondents according to their market perception

The probable reason for such finding might be that the higher educational level of the farmers which contributed towards achieving high environmental orientation among vegetable farmer.

Extension contact

The findings in Figure 10 showed that just about half (49.2%) of the vegetable farmers had medium extension contact followed by exactly one-third (33.3%) had low level and only 17.5% had high level of extension contact.

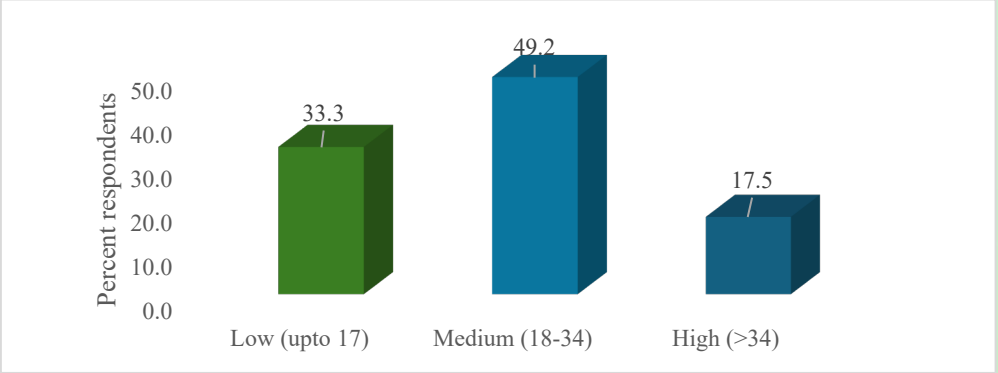


Figure 10. Distribution of the respondents according to their extension contact

The possible reason behind this finding might be that selected respondents from the study areas are the beneficiaries of CIG group members of DAE and majority of the farmers had frequent contact and interaction with the officials of different public and private level extension organizations like DAE, Ministry of Agriculture, Bangladesh.

Awareness on Good Agricultural Practices (GAP) on vegetable cultivation

The extent of awareness of vegetable farmers on various Good Agricultural Practices in vegetable cultivation is discussed below. Table 2 reveals that the distribution of the vegetable farmers based on their awareness level on GAP.

Table 2. Distribution of the respondents according to their awareness score

Awareness categories (Score)	Number	Percent	Mean	SD
Low (up to 51.0)	32	26.7	61.28	10.22
Medium (52-71.0)	68	56.7		
High (>71.0)	20	16.6		
Total=	120	100.0		

It could be inferred that more than half of the respondents (56.7%) had medium awareness level on GAP, 26.7% had low level of awareness and only 16.6% of them had high level of awareness on Good Agricultural Practices (GAP).

Component wise awareness level on GAP among vegetable farmers

The findings of Table 3 shows component-wise awareness level on GAP among vegetable farmers. It could be observed that GAP components like pest and disease management gained high range of awareness score. Awareness score of GAP component land and soil preparation (55.2), nutrient management (52.3), harvesting and post-harvest handling (60.1) were found to be medium level.

Table 3. Component wise awareness level on GAP among vegetable farmers

Sl. #	Component wise awareness score	Awareness score
1.	Land and soil preparation	55.2 (Medium)
2.	Seed / seedling quality parameters	48.8 (Low)
3.	Sowing/transplanting parameters	49.1 (Low)
4.	Nutrient management	52.3 (Medium)
5.	Irrigation management	40.5 (Low)
6.	Pest and disease management	71.5 (High)
7.	Harvesting and post-harvest handling	60.1 (Medium)

Good agricultural practices awareness score on the practices like seed/seedling quality parameters (48.8), sowing/transplanting parameters (49.1) and irrigation management (40.5) were found to be low.

The findings means that the vegetable farmers of the study areas had not a fairly well awareness about Good Agricultural Practices, therefore, it could be inferred that they are not fully aware about all the aspects of GAP.

Adoption level of Good Agricultural Practices (GAP)

The findings revealed in Figure 11 indicated that majority (65.0%) of the vegetable farmers had low level of adoption of Good Agricultural Practices in vegetable cultivation while 26.7% of the study respondent had medium and only a negligible portion of the respondents had low level of adoption.

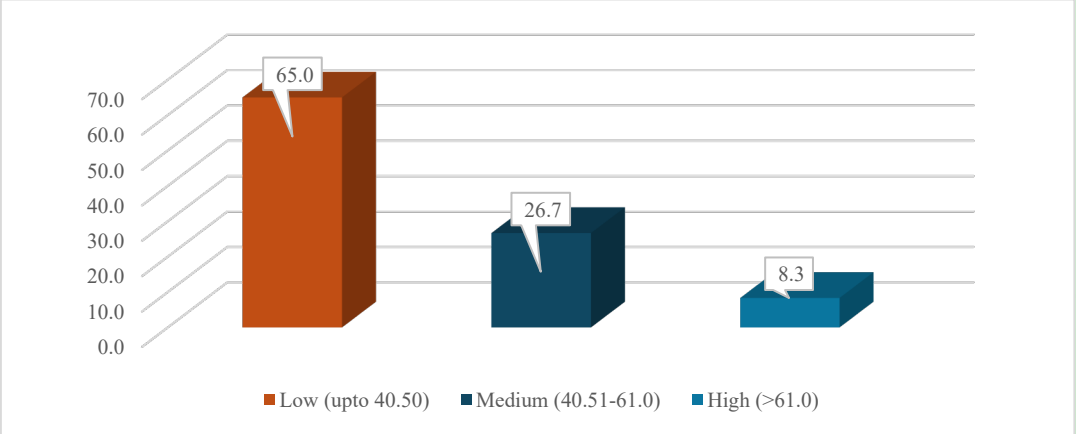


Figure 11. Distribution of the respondents according to their extension contact

The possible reason for such types of findings might be that in the study area, the Good Agricultural Practices are very new idea among the farmer's level. DAE, under the Ministry of Agriculture just started different awareness creation as well as GAP dissemination activities among the farmers. Farmers are gradually getting aware along with adopting different GAP components for cultivation of vegetables by considering environmental as well as in broad context sustainability issue of production of vegetables.

Component wise adoption level of GAP among vegetable farmers

The extent of adoption of Good Agricultural Practices among vegetable farmers was measured with adoption score values. Among the listed seven components of GAP, pest and disease management (61.5) gained highest range of adoption score. The probable reason might be that farmers were benefitted form the adoption of Good Agricultural Practices related to pest and disease management.

Table 4. Component wise adoption level of GAP among vegetable farmers

Sl. #	Component wise adoption score	Adoption score
1.	Land and soil preparation	50.1 (Medium)
2.	Seed / seedling quality parameters	39.5 (Low)
3.	Sowing/transplanting parameters	38.1 (Low)
4.	Nutrient management	45.3 (Medium)
5.	Irrigation management	36.5 (Low)
6.	Pest and disease management	61.5 (High)
7.	Harvesting and post-harvest handling	59.1 (Medium)

It was also found that adoption score for remaining practices viz. land and soil preparation (50.1), nutrient management (45.3) and harvesting and post-harvest handling (59.1) had gained medium level of adoption score. Whereas seed / seedling quality parameters (39.5), sowing/transplanting parameters (38.1) and irrigation management (36.5) gained low level of adoption among the vegetable farmers in the study areas.

Association between extent of awareness and extent of adoption of Good Agricultural Practices by vegetables farmers

For more clarity about the extent of awareness and extent of adoption of GAP, an association between extent of awareness and extent of adoption of GAP situation of the vegetable farmers is presented in Table 5.

Table 5. Awareness and adoption of Good Agricultural Practices by the vegetable farmers

Extent of awareness	Extent of adoption			Adoption Indices	χ2-value
	Low (up to 40.50)	Medium (40.51-61.0)	High (>61.0)		
Low (up to 51.0)	75.8	21.2	3.0	127.3	82.54**
Medium (52-71.0)	78.4	9.8	11.8	133.3	
High (>71.0)	36.1	41.7	22.2	186.1	

** Significant at the 0.01 level of probability, df=4

Analysis of data contained in Table 5 indicates that there were appreciable variations in the level of adoption of GAP by vegetable farmers according to the variations in their extent of awareness. Percentage of farmers with low adoption of GAP was the highest (75.8%) in the low awareness category compared to 78.4% in the medium category and 36.1 percent in the high adoption category. Proportion of the farmers with high adoption was highest (22.2%) in the high awareness category, compared to 11.8% in the medium awareness category and only 3.0% in the low awareness category. These variations were statistically significant at 0.01 level of probability as indicated by the chi-square value of 82.54.

In view of the above findings the null hypothesis was rejected and it was concluded that there is a relationship between the awareness among the farmers and level of adoption of GAP. The adoption indices indicate that the adoption consistently increased from the low awareness category to the high awareness category. Hence, the relationship was positive. The finding indicates that awareness about GAP among the farmers helps to improve their adoption of different components of GAPs.

Relationship between selected characteristics of the respondents and adoption of GAP

This section deals with the relationship between the nine selected characteristics of the respondents and adoption level of GAP by vegetable farmers. The relationships were computed by using the Pearson's product moment correlation co-efficient. The co-efficient of correlation (5% level) was used to test the null hypothesis and analysis is presented in Table 6 as follows.

Table 6. Relationship between selected characteristics of the respondents and adoption of GAP

Focus Issue	Selected Characteristics	Pearson's Product Moment Correlation Coefficient (r) at 118 df
Adoption of GAP by the vegetable farmers	Age	0.086ns
	Education	0.038ns
	Area under vegetable cultivation	0.275**
	Experience in vegetable cultivation	0.474**
	Training received	0.290**
	Annual income	0.040ns
	Market perception	0.365**
	Environmental orientation	0.294**
	Extension contact	0.374**

According to the computed correlation coefficients among the nine selected characteristics of the farmer's age, education, and annual income had no significant relationship with the adoption of GAP by the vegetable farmers. On the other hand, area under vegetable cultivation, experience in vegetable cultivation, training received, market perception and Environmental orientation and extension contact had positive significant relationship with adoption of GAP by the vegetable farmers.

Constraints faced by the farmers in adoption of Good Agricultural Practices (GAPs) in vegetablecultivation

It is evident from the Table 7 that the most important constraint is increased difficulty in management of pest and disease incidence having mean score of 2.7.

Table 7. Item wise constraints faced by the farmers in adoption of Good Agricultural Practices (GAPs) in vegetable cultivation

Constraints	Mean score	RO
Lack of awareness of good agricultural practices	2.5	4th
Lack of knowledge in use of good agricultural practices	2.6	2.5nd
Lack of technical guidance	2.3	6th
Lack of market knowledge	2.4	5th
Lack of local market demand	2.2	7th
Lack of better pricing for GAP	2.6	2.5nd
Increase in cost of production of Good Agricultural Practices	2.0	9th
Decline in income during conversion of conventional farming to good agricultural practices	1.9	10th
Inadequate loan/credit facility	1.7	12th
Unavailability of bio inputs like fertilizers, plant protection chemicals, herbicides etc.	2.1	8th
Increased labour and land management requirements	1.8	11th
Increased difficulty in management of pest and disease incidence	2.7	1st

To counter this constraint promoting group action by the farmers is one of the ways. Various biological methods of control by the farmers as a group would enable them to eradicate the pests and diseases problem as a whole in the study areas. Farmers also have to follow stringent measures under GAP to control pests and diseases. The logistic support of an extension system and government policy for group action would be necessary for managing this constraint.

Lack of knowledge in use of good agricultural practices and Lack of better pricing for GAP having mean score of 2.6, respectively gained the second position in the constraint table and jointly ranked. The reason for this finding might be due to those farmers of the study area as just getting training on GAP for awareness creation on this issue as well as for adoption. Therefore, the knowledge level of the farmers in the study areas still have less awareness as well knowledge regarding GAP. While some of the progressive farmers started to adopt different components of GAP but still their product in the market are not treated especially therefore, they are not getting price fairly.

The last ranked constraint is inadequate loan/credit facility having mean value of 1.7. This finding could be due to that now various farmers are getting credit from different micro-credit organization as well as bank on agricultural practices. Therefore, farmers are not faced high extent of constraint in this regard.

Conclusions and Recommendation

In conclusion, the findings reveal that a majority of vegetable farmers operate small landholdings and possess substantial experience in cultivation, yet face challenges with low training received, market perception, and environmental orientation, underscoring the need for enhanced support and education to improve their overall agricultural effectiveness. While the majority of respondents exhibit a medium level of awareness regarding Good Agricultural Practices (GAP), the varying awareness scores across specific components indicate opportunities for targeted educational initiatives to further enhance farmers' understanding and implementation of these practices.

A significant majority of vegetable farmers have a low level of adoption of Good Agricultural Practices, with pest and disease management emerging as the most adopted component, highlighting the need for strategies to improve overall adoption across all GAP areas. The study highlights that a significant constraint for vegetable farmers lies in the lack of knowledge and better pricing for Good Agricultural Practices (GAP), so there is still a considerable gap in awareness, understanding and adoption of GAP. Factors such as area under cultivation, experience, training received, market perception, environmental orientation, and extension contact demonstrated a positive and significant relationship, underscoring the importance of these elements in enhancing GAP adoption among farmers.

Creating more awareness regarding GAP components among the farmers as well as ultimate consumers would be required which increase the demand for GAP products and thereby contribute to higher income to the farmers. More intensive training, motivational activities and capacity building programs are required for the farmers to enhancing awareness, skill on GAP ultimately increase the adoption. Similar research studies could be conducted in the other vegetable growing areas of the country for making the findings generalize as the current study was limited to only one district.

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Awareness, Perceıved Effect and Mıtıgatıon Strategıes on The Effect of Clımate Change Among Poultry Farmers in Ogun State of Nigeria

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Abstract

Global warming poses a significant threat to poultry production, inducing heat stress that reduces feed intake, egg production, and reproductive capacity, while increasing mortality rates. However, limited research exists on poultry farmers' awareness, knowledge, and perceptions of climate change, which are essential for developing effective adaptation strategies. This study examines poultry farmers' perceptions of climate change in Ogun State, Nigeria. Primary data were collected from 154 registered members of the Poultry Association of Nigeria, Ogun State Chapter (PANOG) using a multistage sampling technique. Data analysis involved the use of descriptive and inferential statistics, including frequency, percentages, and chi-square tests. Results show that 64.5% of poultry farmers were male, 78.3% had tertiary education, and 93.4% were aware of climate change. Over 80% associated climate change with rising environmental temperatures, while more than 70% linked it to increased water intake in poultry birds. Additionally, 75% of respondents identified well-ventilated housing as a mitigation strategy. However, fewer than 50% strongly agreed on the effectiveness of improving feed quality, veterinary services, reducing stocking density, or integrating other livestock. Statistical analysis revealed significant ($P<0.05$) relationships between awareness and factors such as age, education level, experience, and access to information. Furthermore, awareness levels significantly ($P<0.05$) influenced the adoption of mitigation strategies. The study highlights the need for targeted education on climate change impacts and adaptive measures, particularly through feed management, to enhance poultry farmers' resilience and productivity in Ogun State.

Key Words: *Awareness, Perception, Climate change, Mitigation strategies,Poultry farmers, Nigeria.*

Introduction

Climate change has emerged as one of the most pressing global challenges, affecting various sectors, including agriculture. It is primarily caused by the accumulation of greenhouse gases in the atmosphere, leading to rising environmental temperatures, commonly referred to as global warming. This phenomenon has significant implications for food production systems worldwide, particularly in regions highly dependent on agriculture for economic sustenance. Among the most vulnerable agricultural sectors is poultry farming, which is crucial for food security, employment, and economic development in many countries, including Nigeria.

Poultry farming is a major component of the livestock industry and plays a pivotal role in meeting the protein requirements of growing populations. Poultry consists of birds which are of economic value to humans as the primary supplier of meat, egg, and raw materials to industries (feathers, waste products), they are also a source of income to man (Akanwa & Joe-Ikechebelu, 2019). The poultry industry in Nigeria is one of the most well-organized and most commercialized agricultural sub-sectors, contributing significantly to the nation's Gross Domestic Product (GDP). It is estimated to account for 25% of the agricultural GDP and provides a livelihood for millions of people across rural and urban areas (Mackenzie et al., 2020).

According to the Central Bank of Nigeria (CBN, 2019), the poultry industry has an estimated market value of ₦1.6 trillion. The demand for poultry products continues to rise, with an estimated annual production of 180 million birds, 3.8 million of eggs, and over a billion tonnes of poultry meat. However, despite the industry's potential, local production has struggled to meet this growing demand, leading to the smuggling of poultry products into the country (Oloso, 2020). This challenge is compounded by climate change, which negatively impacts poultry production and reduces its productivity (Liverpool-Tasie et al., 2019).

Poultry birds are homeothermic animals, meaning they thrive within specific temperature ranges known as the Thermo-Neutral Zone (TNZ). The TNZ ensures optimal feed conversion, growth, development, and productivity (Aroyehun, 2023). When temperatures exceed or fall below this range, poultry birds experience physiological stress, affecting their performance. In particular, high temperatures lead to heat stress, which reduces feed intake,

lowers egg production, increases mortality rates, and negatively affects reproduction. These adverse effects of climate change on poultry farming necessitate urgent interventions to mitigate its impact and ensure the sustainability of poultry production.

While climate change has been widely recognized as a significant threat to agriculture, there remains a gap in understanding its specific impact on poultry productivity. Several studies (Chah, 2013; Adebisi, 2017; Aroyehun, 2022) have documented the detrimental effects of climate change on livestock, including reduced fertility, poor egg quality, increased disease susceptibility, and higher production costs. However, there is limited information on poultry farmers' awareness, perceptions, and adaptive strategies regarding climate change. Many farmers may be aware of climate change but lack the knowledge and resources to implement effective mitigation measures. As a result, they continue to experience losses due to heat stress, feed inefficiencies, and disease outbreaks.

Research has shown that farmers' socio-economic characteristics, such as age, gender, education level, and access to information sources, play crucial roles in farmers' perception and adaptation strategies (Sesay & Kallon, 2022; Adepoju & Osunbor, 2018). Farmers with higher education levels and access to extension services are more likely to be aware of climate change impacts and adopt appropriate adaptation measures to counteract climate-induced challenges (Adepoju & Osunbor, 2018; Aroyehun, 2022). Those with limited knowledge may struggle to implement appropriate interventions. Additionally, training programs and climate-related information play a critical role in shaping farmers' perceptions and responses. Without adequate knowledge, poultry farmers may fail to adopt adaptive measures such as improving housing conditions, optimizing feeding practices, enhancing veterinary care, and reducing stocking densities to mitigate climate change effects.
Despite government efforts to boost local poultry production, policy frameworks have not fully considered the implications of climate change. In 2015, the Nigerian government implemented measures to promote local production by restricting the importation of poultry products and cracking down on smuggling activities (Amata, 2022). While these policies aimed to enhance domestic poultry farming, they did not address the environmental challenges that threaten the sector's growth. Consequently, many poultry farmers continue to face climate-related obstacles without adequate support or guidance.

Furthermore, Nigeria is expected to be a key driver of global meat consumption in the coming decades (The Economist, 2019). This projection underscores the importance of developing climate-resilient poultry farming systems to meet future food demands. As climate change intensifies, it is imperative to equip poultry farmers with the necessary knowledge and resources to adapt and build resilience against environmental stressors. Sustainable practices, such as climate-smart housing, strategic feeding, genetic selection for heat-resistant breeds, and efficient waste management, must be prioritized to safeguard the industry's future.

Given the critical role of poultry farming in Nigeria's economy and food security, it is essential to assess poultry farmers' awareness, knowledge, and adaptive capacity concerning climate change. Understanding their perceptions and identifying the challenges they face will provide valuable insights into effective mitigation strategies. This study aims to fill the existing knowledge gap by assessing farmers' level of awareness, perceived effects, and mitigation strategies that could reduce the effects of climate change on poultry production.

Hypothesis
Ho_1: No significant relationship between selected socio-economic characteristics of poultry farmers and their awareness of climate change.
Ho_2: No significant relationship was found between their level of awareness and adoption of practices for mitigating the effects of climate change.

Materials and Methods

This study employed a cross-sectional survey design to gather data from members of the Poultry Association of Nigeria, Ogun State Chapter (PANOG). PANOG is divided into six zones, namely, Ijebu, Remo, Egba, Ota, Yewa, and Mowe. A total of 154 poultry farmers were selected using a multi-stage random sampling technique.
In the first stage, purposive sampling was used to select three zones—Ijebu, Remo, and Egba—due to their proximity. The second stage involved proportional random sampling to determine the number of farmers from each selected zone. In the final stage, convenience sampling was employed during monthly meetings, with the assistance of the PAN Ogun State secretary, to recruit farmers who were available and willing to participate.
Data were collected on farmers' socioeconomic characteristics, awareness, perceived effects, and mitigation strategies related to climate change. Descriptive statistics, including frequency and percentages, were used to analyze socioeconomic characteristics and awareness levels. Inferential analysis using chi-square was conducted to test the study's hypotheses and draw relevant conclusions.

Results and Discussion

The socioeconomic characteristics of the poultry farmers were analysed using descriptive statistics. These include gender, age, level of education, farming experience, types of birds raised, number of birds in stock, management system, awareness of climate change and source of awareness.
The results indicate that 64.5% of the respondents were male, with a significant proportion falling within the age groups of 45-54 years (26.3%) and 55-65 years (23.7%). The majority (78.3%) of poultry farmers had tertiary education.
Regarding experience, 38.2% of farmers had 6-10 years of experience, while 25.7% had 11-16 years, suggesting that most respondents were experienced poultry farmers. Half (50.0%) of the farmers raised layer breeds, while only 33.6% reared broilers.

Table 1.0 Socio-Economic Characteristics of Poultry Farmers in the Study Area

Characteristics	Frequency	Percentage
Gender		
Male	95	64.5
Female	54	35.5
Age		
25-34	38	25.0
35-44	31	20.4
45-54	40	26.3
55-65	36	23.7
Above 66	6	3.9
Respondent's level of Education		
Primary	7	4.6
Secondary	22	14.5
Tertiary	119	78.3
Formal education.	4	2.6
Years of Farming Experience		
≤ 5	27	17.8
6-10	58	38.2
11-16	39	25.7
Above 16	27	17,8
Type of birds raised		
Layers	76	50.0
Breeders	19	12.5
Broilers	51	33.6
Number of birds in stock		
< 500	34	22.4
500-1,000	53	34.9
1001-5000	35	23.0
5001-10,000	24	15.8
Above 10,000	5	3.3
Management system in practice		
Deep litter	60	39.5
Battery cage	79	52.0
Semi- intensive	8	5.3
others ----------	4	2.6
Awareness of climate change		
Yes	142	93.4
No	9	5.9
Source of information on climate change		
Newspapers	29	19.1
Radio / TV	46	30.3
Professional colleagues / Association	51	33.3
Extension workers	9.2	9.2
Others ----------	8	5.3

Source: Field Survey, 2024

More than half (52.0%) of the respondents practiced the battery cage system of poultry production, likely due to the high proportion of layer farmers, as battery cages facilitate egg collection.
The majority (93.4%) of respondents reported being aware of climate change, which may be attributed to the high level of education among poultry farmers in the study area. Television and radio were identified as the primary sources of climate change information for these farmers.

Awareness of Climate Change by Poultry Farmers

Table 2.0 indicates a relatively high level of awareness of climate change among poultry farmers in Ogun State. The majority of the farmers were very moderately aware of what climate entails. A significant 79.9% of respondents acknowledged their awareness that climate change involves an increase in environmental temperature (global warming). This is consistent with the findings of Ezihe et al. (2020), who reported that 90.9% of poultry farmers agreed that they are aware of climate change**.** 54.6% are aware that climatic changes can lead to unfamiliar disease symptoms in birds. This awareness highlights the interconnectedness of climate change, environmental factors, and livestock health, which has been documented in previous studies (Thornton et al., 2022).
The majority (75.7%) of the poultry farmers agreed that there have been changes in rainfall patterns in recent years. This result supports the findings of Aroyehun (2022), who reported that 86.7% of the poultry farmers agreed that climate change increases in rainfall.

Table 2.0 Awareness of climate change by Poultry Farmers

Awareness	**Very Aware (VA)** Frq (%)	**Moderately Aware (MA)** Frq (%)	**Somehow Aware (SA)** Frq (%)	**Not Aware (ND)** Frq (%)
Climate change involves increase in environmental temperature (global warming)	120 (79.9%)	19 (12.5%)	6 (3.9%)	4 (2.6%)
Climate change is a global issue	117 (77.0%)	19 (12.5%)	9 (5.9%)	6 (3.9%)
There have been changes in rainfall pattern in recent years	115 (75.7%)	118 (11.8%)	10 (6.6%)	5 (3.3%)
Human activities are responsible for climate change	96 (63.2%)	32 (21.1%)	12 (7.9%)	8 (5.3%)
Weather has become unpredictable	113 (74.3%)	19 (12.5%)	13 (8.6%)	6 (3.9%)
Climatic changes increases unfamiliar diseases symptoms in birds	83 (54.6%)	44 (28.9%)	12 (7.9%)	7 (4.6%)
Flooding is a result of climate change	84 (55.3%)	32 (21.1%)	17 (11.2%)	17 (11.2%)
Poultry contributes to green house gas emission	67 (44.1%)	44 (28.9%)	19 (12.5%)	19 (12.5%)
Dry season is now more prolonged than before.	84 (55.3%)	35 (23.0%)	23 (15.1%)	7 (4.6%)

Source: Field Survey, 2024

Perceived Effects of Climate Change on Poultry Production

Table 3.0, shows perceived effects of climate change on poultry production by the farmers. Over 50% strongly agreed that climate change increases the water intake of poultry birds and increases maintenance costs. However, less that 50% strongly agreed on other listed perceived effects with the least percentage (30.9%) strongly agreeing to climate change effect on quality of feed ingredient. Other listed percieved effect of climate change include rate of feed intake,egg and meat production, growth rate, availability and cost of feed, maintanance cost, diseases susceptibility,mortality rate and income.
About 47.4% of the poultry farmers strongly agree that climatic change reduces the rate of feed intake of birds. Result agrees with Olorede (2021) findings that climate change increases feed intake in birds.While 32.9% of the poultry farmers strongly agree that climate change reduces the availability of feed, 22.4% are neutral. Effect of feed grain availability may be due to hash climatic conditions resulting in low harvest and hence scarcity of feed grain. Poultry farmers who are neutral on climate change effect are between 11.2% and 22.4%. This implies that they are not knowledgeable on climate change effect. Results indicate the need to educate the poultry farmers on the effect of climate change on poultry production.

Table 3.0. Distribution of Respondents on Perceived Effects of Climate Change on Poultry Production

Perceived effects of climate change on poultry production	Strongly Agree (SA) Frq (%)	Agree (A) Frq (%)	Neutral (N) Frq (%)	Strongly Disagree (SD) Frq (%)	Disagree (D) Frq (%)
Climatic changes increase water in take of poultry birds	97 (59.9%)	37 (24.3%)	17 (11.2%)	4 (2.6%)	2 (1.3%)
Climatic changes reduces the rate of feed intake of birds	72 (47.4%)	46 (30.3%)	23 (15.1%)	5 (3.3%)	4 (2.6%)
Climate change limit egg and meat production	72 (47.4%)	48 (31.6%)	22 (14.5%)	3 (2.0%)	5 (3.3%)
Climatic changes slow down the growth of the poultry birds	62 (40.8%)	50 (32.9%)	26 (17.1%)	8 (5.3%)	3 (2.0%)
Climatic changes increases disease susceptibility	52 (34.2%)	41.4 (27.2%)	17.1 (11.3%)	2.0 (3%)	2.0 (3%)
Climate change increase maintenance cost	85 (55.9%)	36 (22.7%)	18 (11.8%)	5 (3.3%)	3.0 (2%)
Climate change increases the cost of feed	62 (40.8%)	42 (27.6%)	30 (19.7%)	5 (3.3%)	6 (3.9%)
Climate change reduces the availability of feed	50 (32.9%)	50 (32.9%)	34 (22.4%)	9 (5.9%)	8 (5.3%)
Climate change reduces the quality of feed ingredient	47 (30.9%)	51 (33.6%)	29 (19.1%)	11 (7.2%)	8 (5.3%)
Climate change increased mortality of birds.	65 (42.8%)	48 (31.6%)	24 (15.8%)	5 (3.3%)	7 (4.6%)
Reduces farmers income	62 (40.8%)	50 (32.9%)	23 (15.1%)	6 (3.9%)	5 (3.3%)

Source:Field survey,2024

Strategies to Mitigate Climate Change in Poultry Production

Table 4.0 shows the mitigation strategies proposed by poultry farmers to counteract the negative effects of climate change on poultry production. 75.0%, 66%, and 63% of the poultry farmers strongly agree that construction of buildings with a good ventilation system, planting to provide shade, and using an efficient cooling system could mitigate the effect of climate change on poultry production, respectively. This result is in agreement with Liverpool-Tasie et al. (2019), who reported that air ventilation and cooling systems are adaptation strategies recommended to be used in response to heat stress. 69% and 73% strongly agreed to maintaining good hygiene and supplying adequate water respectively. While 27% strongly agreed to increased use of veterinary services and use of herbs and spices, 19% strongly agreed to keeping other livestock, and 37.5% were neutral. 12.5% and 13.8% strongly disagree with the use of herbs and spices and keeping other livestock, respectively. This indicates the need for further enlightenment on strategies for building the resilience of poultry against climate change for improved productivity.

Relationship between Selected Socioeconomic Characteristics of Poultry Farmers and their Awareness of Climate Change

The results of the test of hypothesis (Table 5.0), show the relationship between selected socioeconomic characteristics of the poultry farmers and their awareness of climate change. Age, level of education, experience, and information were significantly ($P<0.05$) related to awareness, perception, and measures in mitigating and controlling the effects of climate change. This finding agrees with Okocha et al. (2024), who reported that education and access to information influence farmers' perceptions and adoption of mitigation strategies. The more educated, experienced, and the easier the accessibility to information, the more aware the farmer is about climate change. The result also agrees with Debela et al. (2015), who reported that personal attributes such as age, education, and access to information affect how individuals perceive climate change.

Relationship between the Level of Awareness and Practices for Mitigating the Effects of Climate Change.

Table 6.0 shows that there is a significant ($P<0.05$) relationship between the level of awareness of poultry farmers and farm practices for mitigating the effects of climate change. This shows that the more aware the farmers are about what climate change is, the more their knowledge on the mitigation practices.

Table 4.0. Strategies to Mitigate Climate Change Effect on Poultry Production

Strategies to mitigate climate change effect on poultry production	**Strongly Agree (SA)** Frq (%)	**Agree (A)** Frq (%)	**Neutral (N)** Frq (%)	**Strongly Disagree (SD)** Frq (%)	**Disagree (D)** Frq (%)
Construction of buildings with a good ventilation system	114 (75.0%)	26 (17.1%)	6 (3.9%)	1 (0.7%)	3 (0.2%)
Planting trees to provide shade for the birds	101 (66.4%)	30 (19.7%)	10 (6.6%)	4 (2.6%)	3 (2.0%)
Use of efficient cooling system like fans.	96 (63.2%)	30 (19.7%)	19 (12.5%)	3 (2.0%)	2 (1.3%)
Seeking more information on climate change.	98 (64.5%)	35 (23.0%)	13 (8.6%)	1 (0.7%)	1 (0.7%)
Improving quality of feeds	42.1 (28%)	23.7 (15.6%)	17.1 (11.3%)	9.2 (6.1%)	5.9 (4%)
Increased use of veterinary services	41.4 (27.2%)	31.6 (20.8%)	15.1 (10%)	2.6 (2%)	5.9 (4%)
Maintaining good hygiene.	105 (69.1%)	27 (17.8%)	12 (7.9%)	1 (0.7%)	2 (1.3%)
Vaccination of birds	79 (52.0%)	38 (22.4%)	24 (15.8%)	6 (3.9%)	5 (3.3%)
Supplying adequate water	112 (73.7%)	28 (18.4%)	6 (3.9%)	1 (0.7%)	2 (1.3%)
Decreasing stocking density.	65 (42.8%)	44 (28.9%)	28 (18.4%)	7 (4.6%)	2 (1.3%)
Use of herbs and spices	41 (27.0%)	39 (25.7%)	43 (28.3%)	19 (12.5%)	7 (4.6%)
Keeping other livestock	29 (19.1%)	32 (21.1%)	57 (37.5%)	21 (13.8%)	9 (5.9%)

Source:Field survey,2024

Table 5.0. Relationship between Selected Socioeconomic Characteristics of Poultry Farmers and their Awareness of Climate Change

Socio-economic characteristics	Pearson Chi-Square	Likelihood Ratio	Linear-by-Linear Association	N of Valid Cases
Gender	0.362 (0.548)	0.353 (0.552)	0.359 (0.549)	152
df	1	1	1	
Age	6.729 (0.151)	5.341 (0.254)	3.747 (0.053)	151
df	4	4	1	
Level of Education	40.734 (0.000)	27.675 (0.000)	2.342 (0.126)	152
Experience	11.8189 (0.019)	6.864 (0.143)	0.548 (0.459)	152
df	4	4	1	
Information	44.172 (0.000)	25.881 (0.000)	5.900 (0.015)	148
df	4	4	1	

Source:Field survey, 2024; df= degree of freedom; Significant at $p<0.05$.

Table 6.0. Relationship between the Level of Awareness and Practices for Mitigating the Effects of Climate Change.

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	4.032	1	0.045
Continuity Correction	0.604	1	0.437
Likelihood Ratio	2.244	1	0.134
Linear-by-Linear Association	4.006	1	0.045
N of Valid Cases	152		

Source: Field survey, 2024

Conclusion

The study indicates a high level of awareness among poultry farmers in Ogun State regarding the impacts of climate change on poultry production. Despite this awareness, there is a pressing need to implement effective mitigation strategies to address the adverse effects of climate change on poultry farming.

As the evidences of climate change are becoming more pronounced all over the world and in Nigeria, adopting climate-smart agricultural practices, improving infrastructure, enhancing veterinary services, good housing systems, manipulation of feed and feeding systems, supplying adequate water of good quality, ensuring adequate stocking density, and capacity building are essential steps towards building climate-resilient poultry farming systems in the area. Since the majority of poultry farmers got climate change information from radio and TV programs, enlightenment programs should be sponsored on the media (particularly radio and television) to create more awareness on mitigation and adaptive strategies that can reduce the effects of climate change on poultry production.

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Aged Garlic Extract: Bioactive Components and Functional Properties

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Abstract

Garlic, a member of the Liliaceae family, has approximately 15 genera and more than 700 species, with Allium sativum L. being the most common. This review study evaluated the bioactive compounds and functional properties of aged garlic. Aged garlic extract is a commercial product obtained by ageing sliced fresh garlic in aqueous ethanol at room temperature for over ten months. This extract contains characteristic sulfur-containing compounds such as S-1-propenylcysteine and S-alliin, which are responsible for garlic's antioxidant, antihypertensive, and immunomodulatory effects. Previous studies have shown that aged garlic extract has high bioavailability and exhibits biological activity in both animal and human studies. Research has revealed that this extract offers pharmacological effects, such as immune-enhancing and cardiovascular protective properties. Furthermore, it has been found to have higher antioxidant effects compared to fresh garlic. The amount of S-alliin in aged garlic extract has been reported to range from 1.6 to 2.4 mg/g (dry weight). Studies show that the total flavonoid and flavonol concentrations in aged garlic extract are higher than in fresh garlic. Sensory evaluations indicate that the "sharp" odor in aged garlic extract is significantly reduced, while "spicy," "acidic," "metallic," and "caramelized" characteristics are more pronounced compared to fresh garlic. This review provides comprehensive information on the bioactive compounds of aged garlic extract and its health effects, offering valuable insights into its potential use in functional foods and pharmacology.

Key Words: *Allium sativum* L.*, Aged garlic, bioactive compounds, antioxidant capacity, pharmacological activity*

Özet

Yıllanmış Sarımsak Ekstraktı: Biyoaktif Bileşenleri ve Fonksiyonel Özellikleri

Sarımsak, Liliaceae ailesine ait olup yaklaşık 15 cins ve 700'den fazla türe sahiptir. En yaygın sarımsak türü *Allium sativum* L.'dir. Bu derleme çalışmasında, yıllanmış sarımsağın biyoaktif bileşikleri ve fonksiyonel özellikleri değerlendirilmiştir. Yıllanmış sarımsak ekstraktı, dilimlenmiş taze sarımsakların sulu etanol içinde oda sıcaklığında on aydan uzun bir süre olgunlaştırılmasıyla elde edilen ve Uzak Doğu'da sıklıkla tüketilen ticari bir üründür. Bu ekstrakt, hazırlanma sürecine bağlı olarak yüksek oranda S-1-propenilsistein ve S-allilsistein gibi kükürt içeren karakteristik bileşikler içermektedir. Söz konusu bileşikler, yıllanmış sarımsağın antioksidan, antihipertansif ve immünomodülatör etkilerinden sorumludur. Yıllanmış sarımsak ekstraktının yüksek biyoyararlanıma sahip olduğu ve hem hayvan hem de insan çalışmalarında biyolojik aktivite gösterdiği daha önceki araştırmalarda belirlenmiştir. Yapılan çalışmalar, bu ekstraktın bağışıklık sistemini güçlendirici ve kardiyovasküler koruyucu özellikler gibi çeşitli farmakolojik etkiler sunduğunu ortaya koymuştur. Ayrıca, antioksidan özellikleri açısından taze sarımsağa kıyasla daha yüksek etki gösterdiği tespit edilmiştir. Yıllanmış sarımsak ekstraktında S-allilsistein miktarının 1.6–2.4 mg/g (kuru ağırlık) aralığında olduğu bildirilmiştir. Çalışmalar, yıllanmış sarımsak ekstraktının toplam flavonoid ve flavonol konsantrasyonlarının taze sarımsağa göre daha yüksek olduğunu göstermektedir. Duyusal değerlendirmelerde ise yıllanmış sarımsak ekstraktında "keskin" koku önemli ölçüde azalırken, "baharatlı", "asitli", "metalik" ve "karamelize" özelliklerin taze sarımsağa kıyasla daha belirgin olduğu bildirilmiştir. Bu derleme çalışması, yıllanmış sarımsak ekstraktının biyoaktif bileşikleri ve sağlık üzerine etkileri hakkında kapsamlı bilgiler sunarak, fonksiyonel gıda ve farmakoloji alanlarındaki potansiyel kullanımına dair önemli veriler sağlamaktadır.

Anahtar Kelimeler: *Allium sativum* L.*, Yıllanmış sarımsak, biyoaktif bileşikler,antioksidan kapasite, farmakolojik aktivite,*

Giriş

Sarımsak, **Liliaceae** ailesine ait olup yaklaşık 15 cins ve 700'den fazla türe sahiptir. Bu türler arasında en yaygın olanı *Allium sativum* L.'dir. Sarımsak (*Allium sativum* L.), kalp hastalıkları, kanser ve enfeksiyonlar dahil olmak üzere çeşitli hastalıkların önlenmesi ve tedavisinde uzun süredir kullanılmaktadır (Hiramatsu ve ark., 2016). Aynı zamanda kanser, diyabet, enfeksiyon ve felç gibi hastalıkların gelişme riskini azaltmada sahip olduğu terapötik potansiyel sayesinde dikkat çeken önemli bir bitkisel üründür. Bu terapötik etkinlik, sarımsağın kimyasal bileşenlerinin güçlü biyolojik aktivitelerine atfedilmektedir (Cervantes ve ark., 2013). Sarımsak, çeşitli formülasyonlarda kullanılabilen değerli bir bileşen olup, bunlardan biri de yıllanmış sarımsak ekstraktıdır. Bu ekstrakt, dilimlenmiş çiğ sarımsağın oda sıcaklığında %15–20 oranında sulu etanol içinde 10 ila 20 ay boyunca bekletilmesiyle elde edilmektedir. Olgunlaştırma sürecinin ardından ekstrakt süzülür ve düşük sıcaklık ile düşük basınç altında konsantre hale getirilir. Son aşamada ise etanol çözeltisi uzaklaştırılabilir ve ürün toz formuna dönüştürülebilir (Ohkubo ve ark., 2017; Elosta ve ark., 2017). Bu olgunlaşma sürecinde, sarımsaktaki keskin kokulu ve tahriş edici bileşikler, kokusuz, daha yumuşak ve güvenli sülfürlü bileşiklere dönüşmektedir (Elosta ve ark., 2017). Bu işlem sırasında allisin miktarında azalma olurken; S-alil sistein (SAC, 1.6–2.4 mg/g kuru madde), S-alil merkaptosistein (SAMC), suda çözünür allisin türevleri ve selenyum gibi organosülfür bileşiklerinin düzeylerinde artış gözlemlenmektedir. Bu bileşiklerin tümü güçlü antioksidan özellikler göstermekte olup, yıllanmış sarımsak ekstraktının sağlık açısından önemli faydalar sunmasına katkı sağlamaktadır (Elosta ve ark., 2017).

Yıllanmış sarımsak ekstraktı, taze sarımsağın oda sıcaklığında uzun süreli ekstraksiyonuyla elde edilen kokusuz bir ürün olup, yüksek biyoyararlanıma sahiptir. Hem hayvan hem de insan çalışmalarında in vitro olarak biyolojik aktivite göstermiştir. Bu ekstrakt, özellikle yaşlanma süreci sırasında oluşan SAC ve SAMC açısından zengindir. Bu durum, yıllanmış sarımsak ekstraktına taze sarımsak ve diğer ticari sarımsak takviyelerine kıyasla daha yüksek antioksidan aktivite kazandırmaktadır (Borek, 2001). Yıllanmış sarımsak ekstraktı 50 yılı aşkın süredir üretilmesine rağmen, aroma profiline ilişkin çalışmalar oldukça sınırlıdır. Üretim süreci boyunca aroma bileşiminde değişiklikler meydana gelmekte; sarımsağa özgü keskin koku büyük ölçüde ortadan kalkmaktadır. Keskin kokudan sorumlu tiyosülfinat ve sülfit bileşiklerinin parçalanarak veya başka bileşiklere dönüşerek kaybolduğu, buna karşılık kükürt içermeyen aroma aktif bileşiklerin olgunlaşma sürecinde çeşitli kimyasal reaksiyonlarla ortaya çıktığı düşünülmektedir (Abe ve ark., 2020).

Bu derleme çalışması, yıllanmış sarımsak ekstraktının aroma bileşenleri ve sağlık üzerindeki olumlu etkilerini ayrıntılı biçimde ele alarak, bu doğal ürünün fonksiyonel gıda ve farmakolojik preparat olarak potansiyel kullanım alanlarına ışık tutmayı amaçlamaktadır.

Sağlık üzerine faydaları

Kardiyovasküler hastalıklar, her yıl yaklaşık 17,9 milyon kişinin ölümüne neden olmakta ve tüm küresel ölümlerin %31'ini oluşturarak dünya genelinde başlıca ölüm nedeni olarak kabul edilmektedir. Hipertansiyon ve hiperlipidemi, kardiyovasküler hastalıkların en önemli iki risk faktörü arasında yer almaktadır. Hipertansiyon, dünya genelinde 1 milyardan fazla yetişkini (yaklaşık her dört kişiden birini) etkilemekte ve 70 yaş altı erken ölümlerin yaklaşık %40'ından sorumlu tutulmaktadır (Wlosinska ve ark., 2020). Avrupa'da, kardiyovasküler olay riski taşıyan bireylerle gerçekleştirilen randomize, çift kör, plasebo kontrollü bir çalışmada; bir yıl boyunca günlük 2400 mg yıllanmış sarımsak ekstraktı tüketiminin, koroner arter kalsifikasyonunun ilerlemesini anlamlı düzeyde yavaşlattığı, kan glikoz seviyelerini düşürdüğü ve sistolik kan basıncını azalttığı tespit edilmiştir (Wlosinska ve ark., 2020).

Son yıllarda yapılan klinik çalışmalar, tedavi altındaki ancak kan basıncı yeterince kontrol altına alınamayan hipertansiyon hastalarında sarımsak preparatlarının olumlu etkilerine dair umut verici sonuçlar ortaya koymuştur (Mahdavi-Roshan ve ark., 2016; Sobenin ve ark., 2009). Elosta ve ark. (2017) tarafından gerçekleştirilen bir çalışmada, sarımsak ve yıllanmış sarımsak ekstraktlarının antioksidan aktiviteleri ABTS [2,2'-azino-bis(3-etilbenzotiyazolin-6-sülfonik asit)] radikal süpürme analizi ile değerlendirilmiştir. Elde edilen sonuçlar, her iki ekstraktın da $ABTS^{+}$ radikallerini temizleme kapasitesi sayesinde anlamlı düzeyde antioksidan özellik gösterdiğini ortaya koymuştur. Özellikle, yıllanmış sarımsak ekstraktının taze sarımsak özütüne kıyasla daha yüksek bir Trolox Eşdeğer Antioksidan Kapasitesi'ne (TEAC) sahip olduğu belirlenmiştir. Bu bulgu, yıllanmış sarımsak ekstraktında bulunan stabil organosülfür bileşiklerinin (örneğin SAC ve SAMC) artmış biyoyararlanımı ve antioksidan potansiyeli ile ilişkilendirilmektedir.

Yıllanmış sarımsak ekstraktının antioksidan özellikleri, artan metabolizma hızı veya kronik inflamasyon sonucunda oluşan reaktif oksijen türlerini (ROS) azaltarak, aterosklerozun erken bir göstergesi olan endotel disfonksiyonunu önlemeye yardımcı olur (Tsuneyoshi, 2020). Rastgele, çift kör, plasebo kontrollü bir beslenme müdahalesinde, üç ay boyunca günde 400 mg sarımsak ekstraktı alımının antioksidan durumu artırdığı ve bunun sonucunda obez bireylerde C-reaktif protein (CRP), düşük yoğunluklu lipoprotein kolesterol (LDL), yüksek yoğunluklu lipoprotein kolesterol (HDL), trigliseritler ve plazminojen aktivatör inhibitörü-1 (PAI-1) gibi endotel biyobelirteçlerinin düzenlenerek kardiyovasküler riskin azaldığı rapor edilmiştir. Ayrıca, randomize, çift kör,

plasebo kontrollü bir klinik çalışmada, yıllanmış sarımsak ekstraktında bulunan organosülfür bileşiklerinin obezite kaynaklı inflamasyon üzerindeki etkileri değerlendirilmiştir. Bu çalışmada, yıllanmış sarımsak ekstraktının içerdiği S-alil sistein (SAC) gibi bileşiklerle sistemik inflamasyon arasında anlamlı düzeyde negatif bir korelasyon saptanmıştır. Katılımcılar, altı hafta boyunca günde 3,6 gram yıllanmış sarımsak ekstraktı takviyesi almış ve bu sürenin sonunda SAC'nin hidrojen sülfür (H_2S) üretimini artırarak obeziteye bağlı inflamasyonu azalttığı belirlenmiştir. H_2S, vücutta doğal olarak bulunan; antiinflamatuar, vazodilatör ve antioksidan etkilere sahip önemli bir sinyal molekülü olarak bilinmektedir (Xu ve ark., 2018).

Metabolik sendrom, abdominal obezite, hipertansiyon, aterojenik dislipidemi, protrombotik ve proinflamatuar durumları içeren bir dizi metabolik bozukluktan oluşan bir rahatsızlıktır. Bu sendrom, etkilenen bireylerde tip 2 diyabet gelişme riskini yaklaşık beş kat, kardiyovasküler hastalık riskini ise iki kat artırmaktadır (Samson & Garber, 2014). Son yıllarda yapılan klinik araştırmalar, yıllanmış sarımsak ekstraktının bu metabolik bozuklukların yönetiminde umut verici sonuçlar ortaya koyduğunu göstermektedir. Örneğin, 24 hafta boyunca günde 1.2 gram yıllanmış sarımsak takviyesi uygulanan bireylerde plazma adiponektin seviyelerinde anlamlı artış gözlenmiş ve buna paralel olarak metabolik sendrom risk faktörlerinde belirgin iyileşmeler rapor edilmiştir (Gómez-Arbeláez ve ark., 2013).

Klinik öncesi çalışmalarda, yıllanmış sarımsak ekstraktının altı günlük uygulama sonrası doza bağlı olarak yara iyileştirme potansiyeli gösterdiği bildirilmiştir (Ejaz ve ark., 2009). Başka bir çalışmada, yıllanmış sarımsak ekstraktı ile beslenen farelerde nöronal nitrik oksit sentaz (nNOS) aracılığıyla kolon düz kas gevşemesinde artış gözlenmiş, enterik sinir sistemi (ENS) hücrelerinde proliferasyonun teşvik edildiği ve ekstraktın belirgin nöroprotektif etkiler gösterdiği saptanmıştır. Bu bulgular, yaşlanmaya bağlı kolorektal dismotilite belirtilerinin azaltılmasında yıllanmış sarımsak ekstraktının potansiyel faydalarını ortaya koymaktadır. Çalışma aynı zamanda, yaşlı farelerde gastrointestinal (GI) motilite özelliklerinin detaylı karakterizasyonunu sunarak, yıllanmış sarımsak ekstraktının GI motilite bozuklukları ve ENS hücre işlevleri üzerindeki olası terapötik etkilerine dikkat çekmektedir (Ohishi ve ark., 2025). Elde edilen sonuçlar, bu doğal ürünün yaşa bağlı sindirim sistemi disfonksiyonlarının yönetiminde umut vadeden bir yaklaşım olabileceğini göstermektedir.

Bitkilerden elde edilen doğal ajanlar, takviyeler, antibiyotikler ve kanser önleyici ilaçların geliştirilmesinde yoğun şekilde araştırılmaktadır. Bu kapsamda sarımsak, hem bir gıda maddesi olarak hem de geleneksel tıpta yaygın biçimde kullanılmaktadır. Yapılan bilimsel çalışmalar, sarımsak ve özellikle yıllanmış sarımsak ekstraktının çeşitli kanser türlerinin önlenmesi ve tedavisinde önemli bir potansiyele sahip olduğunu ortaya koymuştur (Tanaka ve ark., 2006; Jikihara ve ark., 2015; Ohkubo ve ark., 2018; Ishikawa ve ark., 2006; Li ve ark., 2019).

Ayrıca, yıllanmış sarımsak ekstraktının anlamlı antiinflamatuvar özellikler sergilediği ve özellikle oral bakteriyel enfeksiyonların tetiklediği yaygın bir kronik inflamatuvar hastalık olan periodontitis üzerinde olumlu etkiler sağladığı gösterilmiştir. İlgili çalışmalar, yıllanmış sarımsak ekstraktı uygulamasının inflamatuvar semptomları belirgin şekilde azalttığını bildirmiştir (Ohtani ve ark., 2020; Nango ve ark., 2023).

Aroma bileşikleri

Yapılan bir çalışmada, allisin ve S-metilmetantiosülfinat gibi sülfür içeren aroma maddelerinin, taze sarımsağın baskın aroma bileşenleri olduğu, ancak bu bileşiklerin yıllanmış sarımsak ekstraktında bulunmadığı bildirilmiştir. Yaşlanma süreci sırasında, tiyosülfinatlardaki azalmanın, yıllanmış sarımsak ekstraktının keskin kokusunun kaybolmasına yol açtığı saptanmıştur (Abe ve ark., 2020). Aynı çalışmada, aroma-aktif bileşiklerin seyreltme faktörleri (FD), gaz kromatografisi-olfaktometri (GC-O) tabanlı aroma ekstrakt seyreltme analizi (AEDA) yöntemi kullanılarak belirlenmiştir. Elde edilen verilere göre, yıllanmış sarımsak ekstraktında $FD \geq 1$ değerine sahip toplam 39 farklı bileşik tanımlanmış ve bu bileşiklerin, meyveli, fenolik, fındıksı ve sülfürlü aromalar gibi çeşitli aroma karakterlerini sergilediği gözlemlenmiştir. Çalışma, yıllanmış sarımsak ekstraktının kompleks bir aroma yapısına sahip olduğunu ve aroma profilinde esterler, aldehitler, fenoller, pirazinler ve laktonlar gibi bileşiklerin yanı sıra sülfür içeren bileşiklerin de önemli bir rol oynadığını bildirmiştir (Abe ve ark., 2020). Abe ve ark. (2020) tarafından yapılan bir diğer çalışmada, taze dilimlenmiş sarımsak ile yıllanmış sarımsak ekstraktı duyusal analiz yöntemiyle kıyaslamıştır. Araştırma bulguları, taze sarımsakta "keskin" kokunun öne çıkan baskın özellik olduğunu, ancak diğer aroma bileşenlerinin daha düşük yoğunluklarda tespit edildiğini göstermektedir. Bununla birlikte, yaşlandırma işleminin sarımsağın aroma profilini önemli ölçüde değiştirdiği gözlemlenmiştir. Yıllanmış sarımsak örneklerinde, "keskin" notanın anlamlı derecede azaldığı, buna karşın "baharatlı", "asidik", "metalik" ve "karamel" notalarının belirgin şekilde ön plana çıktığı tespit edilmiştir. Bu sonuçlar, yıllanmış sarımsak ekstraktının, taze sarımsağa kıyasla daha az keskin fakat daha kompleks ve zengin bir aroma profiline sahip olduğunu ortaya koymaktadır.

Tartışma

Derlenen çalışmalar, yıllanmış sarımsak ekstraktının sağlık üzerinde olumlu etkiler gösterdiğini ortaya koymaktadır. Yıllanmış sarımsak ekstraktının antioksidan ve anti-inflamatuvar özellikleri, hipertansiyon, hiperlipidemi, tip 2 diyabet ve obezite gibi metabolik hastalıklar üzerinde olumlu etkiler sunmaktadır. Klinik veriler, yıllanmış sarımsak ekstraktının reaktif oksijen türlerini azaltarak endotel fonksiyonlarını iyileştirdiğini ve ateroskleroz sürecini yavaşlattığını göstermektedir. Ayrıca, antioksidan özellikleri açısından taze sarımsağa kıyasla daha yüksek bir etkiye sahip olduğu tespit edilmiştir. Çalışmalar, yıllanmış sarımsak ekstraktının toplam flavonoid ve flavonol konsantrasyonlarının taze sarımsaktan daha yüksek olduğunu göstermektedir. Duyusal değerlendirmelerde, yıllanmış sarımsak ekstraktında "keskin" koku önemli ölçüde azalırken, "baharatlı", "asidik", "metalik" ve "karamelize" özelliklerin taze sarımsağa kıyasla daha belirgin olduğu bildirilmiştir. Mevcut literatür verileri, yıllanmış sarımsak ekstraktının fonksiyonel bir gıda bileşeni olarak kullanım potansiyelini güçlendirmektedir. Bu alandaki çalışmaların daha da detaylandırılması, bu doğal bileşiğin daha geniş bir kitleye fayda sağlayacak şekilde kullanılması için önemli fırsatlar yaratacaktır.

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Oviductal Impaction in Three Budgerigars (*Melopsittacus undulatus*): A Case Report and Systematic Review

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Abstract

Three cases of oviductal impaction in budgerigars (*Melopsittacus undulatus*) caused by torsion and egg binding in the oviduct are described in this study. In two birds, egg bound diagnosis could be made by radiography, and manual transcloacal removal was performed under general anesthesia. Exploratory coeliotomy was performed in one bird with salpingitis and torsion. Clinical findings, diagnostic method, treatment, and results of three cases are presented. Reproductive tract diseases are common in avian practice, especially among female birds. We conducted a systematic review of the case report and case series on oviductal impaction in birds In three major databases, relevant articles published in 1980–2024 were identified. Most information on studies was recorded in India. Data from 27 patients presented as cases in 21 different studies were evaluated. This study performs a systematic review of the species of birds, methods, treatments, and prognoses described in the literature about oviductal impaction in birds and is intended to be reference material for students, researchers, and clinicians.

Keywords: *Dystocia, Birds, Oviduct impaction, Egg bound, Salphingohysterectomy*

Introduction

Egg binding and dystocia are the most common emergencies in many species of adult female birds in captivity. (Harcourt- Brown, 1996; Crosta et al., 2003) It refers to delayed ovulation due to mechanical obstruction or suppression as a result of cloacal dysfunction. (Vavlas et al. 2025) Dystocia is more complicated than just egg entrapment. There are many underlying causes, including functional (malformed eggs, cloacal masses, oviductal pathologies, obesity), metabolic (vitamin E, selenium deficiency, calcium imbalance and nutritional deficiency), environmental (temperature changes, lack of exercise and stressors) and hereditary diseases (Echols and Speer, 2022; Vavlas et al., 2025). Small birds such as canaries, nightingales and parakeets are much more affected by the disease (Lorenzo et al., 2003; Harcourt-Bown, 1996).
Clinical symptoms include dyspnea, unilateral or bilateral paresis of the legs, depression, and lethargy (Vavlas et al., 2025). Diagnosis is based on clinical signs, palpation and imaging techniques such as radiography, fluoroscopy, CT and US. (Vavlas et al., 2025; Crosta et al., 2003; Harcourt- Brown, 1996)
Treatment options can be categorized as follows: medical treatment; ovocentesis; mechanical support; surgical treatment. Sometimes, in cases diagnosed early, fluid replacement, calcium supplementation, and analgesia can successfully stabilize the patient. (Vavlas et al., 2025) Salpingohysterotomy and salpingohysterectomy are indicated in cases of postovulatory stasis or dystocia where medical treatment fails. (Gorham et al., 1992; Mehler and Bennett, 2022)
This study describes a case report of three budgerigars suffering from oviduct impaction. We then present a systematic review of the literature on oviductal impaction in birds, including diagnostic methods, treatments, and prognosis.

Case Reports

Case 1

A 3-year-old female budgerigar (*Melopsittacus undulatus*) was evaluated because of labored breathing and tail wagging. Befor presented the bird increased territorial behavior of approximately one weeks duration and laid four eggs in cage (Figure 1). The bird's diet consisted of commercial budgerigar food and table food. On initial evaluation, the bird was lethargic and depressed. The physical examination revealed a swelling in the abdomen, and the egg could be palpated within it. To facilitate a complete physical examination, whole-body radiography was performed. Latero lateral whole-body radiography revealed a smooth, mineralized egg of normal shape, localized to the caudal coelomic cavity (Figure 2). Based on the history, clinical signs, and findings from the physical examination, the case was diagnosed as an egg-bound condition. The bird was placed in an oxygen chamber with Ventolin for 15 minutes. Prior to induction of anesthesia with isoflurane via a mask, the animal was

premedicated with intramuscular butorphanol, 2 mg/kg (Butomidor©; Richter Pharma, Wels, Austria). The patient was placed in dorsal recumbency and the vent region was cleaned with the isotonic and lubricated with 7.5% Povidone iodine. The retained egg was gently manipulated with a hand and the egg was removed carefully through the cloacal opening without breaking (Figure 3). The patient was treated with enrofloxacin (25 mg/kg PO q24h for 10 days; compounded suspension), meloxicam 0.5 mg/kg PO q12h (Metacam©; Boehringer Ingelheim, Ingelheim am Rhein, Germany), and calcium multivitamin supplement. The bird recovered uneventfully in 2 weeks, and there was no further follow-up from the owner.



Figure 1. Increased nesting behavior and four eggs laid.



Figure 2. Lateral radiographic view of a budgerigar (*Melopsittacus undulatus*) with an mineralized egg.



Figure 3. Egg that removed by manual trans cloacal removing technique in case 1.

Case 2

A 2-year-old female budgerigar (*Melopsittacus undulatus*) was presented to Istanbul University Cerrahpasa Faculty of Veterinary Science Hospital, Emergency Clinics with a primary complaint of straining, loss of appetite and tail wagging. The bird had no previous egg-laying history, and no clear diagnosis could be made on clinical examination and palpation. To facilitate diagnosis, whole-body radiography was performed. Ventral whole-body radiography revealed an incompletely formed or broken egg localized to the caudal coelomic cavity (Figure 4). The bird was then anesthetized with the same technique as case 1, for examination of the cloacal opening of the oviduct. The patient was placed in dorsal recumbency and the vent region was cleaned with isotonic and lubricated with 7.5% Povidon iyodinThe egg pieces were not visible in the terminal oviduct; however, the eggshell was removed using forceps. The removed shell pieces were non-mineralized and soft. The bird recovered from the

anesthesia after the lavage and aspiration of the cloacal opening. No bleeding or prolapse complications were observed after the intervention. The bird was treated with the same medical protocol in case 1. no egg-like residues were found in the control x-ray. The patient was followed up for 2 weeks, and no complications were reported.



Figure 4. Radiography shows that a broken egg localized to the caudal coelomic cavity.

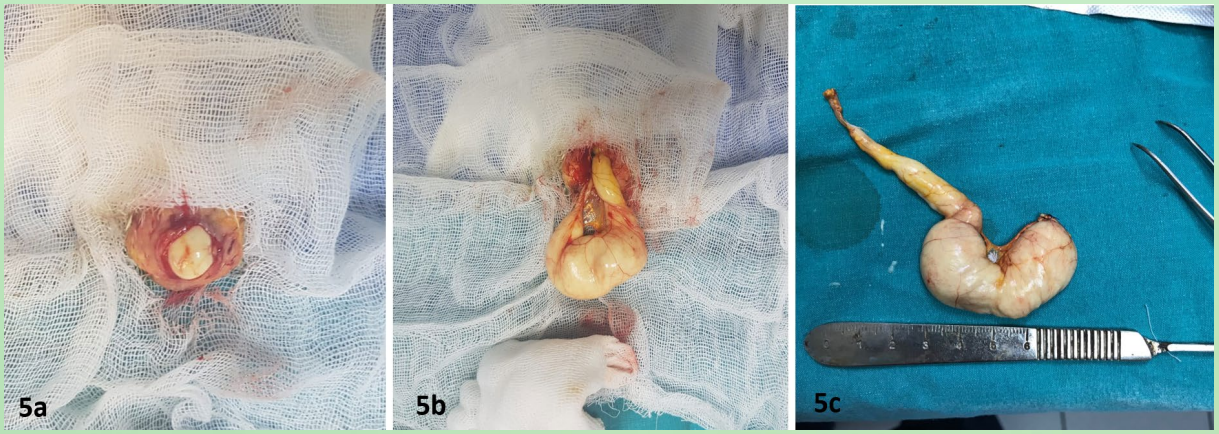


Figure 5. Salphyngohiysterectomy operation descreibed in case 3.

Case 3

A two-year-old female budgerigar (*Melopsittacus undulatus*) presented to our clinics with symptoms including weakness, reduced activity, swelling in the abdomen and inappetence. The bird had been treated with antibiotics and vitamins by the referring veterinary clinic for 5 days, but had failed to respond to treatment. Given the physical findings and history, an ultrasound examination was performed. The ultrasound examination of the coelomic cavity revealed a sac containing hypoechoic contents. There was no definitive diagnosis, but an experimental laparotomy was recommended.

The bird was then anesthetized with the same technique as cases 1 and 2. The bird was placed in dorsal recumbency. Feathers were plucked from the surgical site, which was prepared aseptically using chlorhexidine scrub and sterile saline. A sterile gauze drape was placed over the bird. A standard ventral midline approach to the coelomic cavity was performed. Skin and abdominal muscle were incised and a distended oviduct was easily seen (Figure 5a). The oviduct appeared torsioned (Figure 5b). All ligations were made manually, with 4/0 monofilament absorbable suture (Maxon, Covidien, Minneapolis, MN, USA), and the oviduct was removed. The oviduct was removed as far proximally as possible (Figure 5c). Closure of the abdominal cavity was performed in two layers in a simple interrupted pattern. The bird died in the anesthetic recovery period.

Materials and Methods

Search Methods and Inclusion Criteria

A systematic review of the case reports and case series was conducted searching PubMed, EBSCOhost, and Google Scholar databases using the keywords dystocia, egg binding, oviduct impaction, prolapse, salphingitis, etc., for articles published up to January 2025. To identify different articles in the databases and search engines, keywords were combined using the Boolean operators “AND” and “OR”. The documents were screened for the presence of the keywords in the title and abstract. This systematic review followed the PRISMA (Preferred Reported Items for Systematic Review and Meta-Analyses) guidelines as shown in Figure 6. (Page et al., 2021).

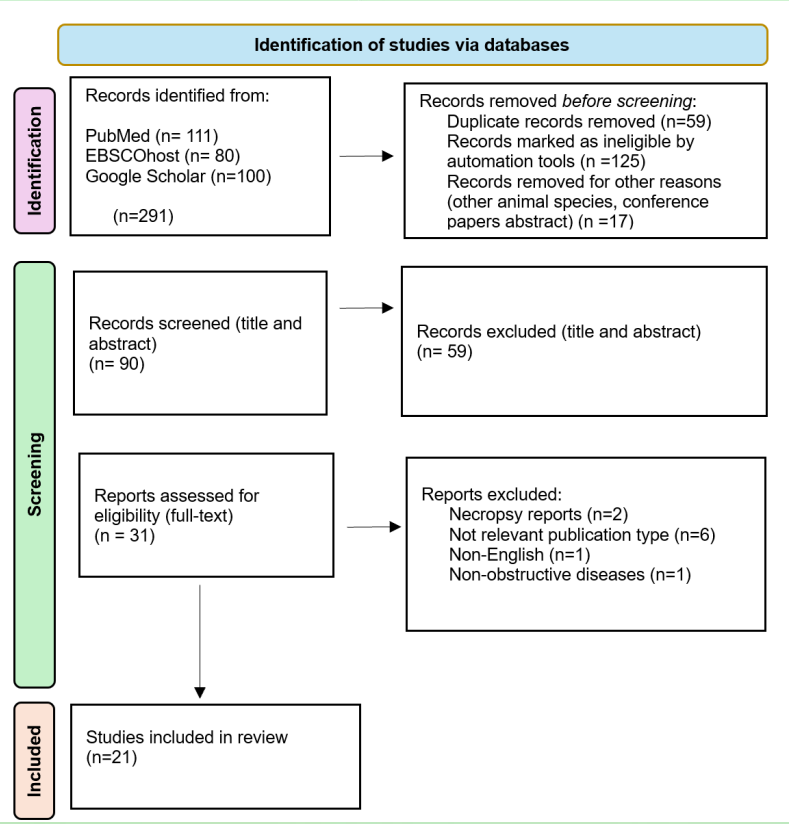


Figure 6. PRISMA flow diagram to select the included studies

The inclusion criteria of the primary studies were based on PICOS (Population, Intervention, Comparison, Outcomes, Study design). Scientific articles with the following designs were included: clinical case reports and case series. The studies included in this review were required to report data on clinical signs, treatments, and prognosis that had been used and/or observed in birds. Aviary birds, poultry, and wild birds were included in the study.

Selection of Studies and Data Collection

Two independent reviewers assessed the primary studies after excluding the duplicates identified from three search databases. Studies were screened based on a two-step assessment. The first step was the assessment of both titles and abstracts of the studies. The unsuitable studies were excluded, and the assessment continued to the second step, which involved a full-text screening. The appropriate studies were then classified as suitable for the systematic review and presented in Table 1, where they are organized based on the alphabetical order of the first author's surname. The following data were extracted from each of the selected studies.

1) Study characteristics (author's name, year of publication, journal, country, database)
2) Patient characteristics (bird's scientific names, age, number of patient in a study)
3) Oviductal impaction conditions characteristics (clinical signs, diagnostic methods, cause of impaction)
4) Intervention characteristics (surgical versus nonsurgical treatment options, complications, prognose)
5) Main results of the included studies.

Results

The studies were conducted between 1993 and 2024. Most of the studies were recorded in India, with 12 out of 21 studies conducted there. Data from 27 patients presented as cases in 21 different studies were evaluated. The species distribution was as follows: *Melopsittacus undulatus, Aratinga nenday, Eclectus roratus, Psittacula eupatria, Columba livia, Gallus gallus domesticus, Nymphicus hollandicus, Spheniscus demersus, Columba livia domesticus, Agapornis, Dromaius novaehollandiae, Anas platyrhynchos domesticus*. The distribution of the bird species and numbers that presented oviduct impaction in the analyzed literature is presented in Table 2.
The most frequent clinical signs were abdominal distension and swelling, and anorexia. Palpation and radiography have been documented as a strategy for diagnosing mineralized egg binding in birds. Additionally, in cases of oviductal impaction with hernia, torsion, or non-mineralized eggs, ultrasound, tomography, cytology, and hematology are recognized as diagnostic methods (Table 3).

Table 1. Studies for this systematic review

Author(s)	Year	Journal	Country	Database
Amin et al.	2019	SKUAST Journal of Research	India	PubMed
Anderson et al.	2018	Journal of Avian Medicine and Surgery	USA	PubMed
Apurva et al.	2022	The Science World a monthly e magazine	India	PubMed
Bel et al.	2015	Bulletin UASVM Veterinary Medicine	Romania	EBSCOhost
Bharathidasan et al.	2019	Journal of Entomology and Zoology Studies	India	PubMed
Chaudhari et al.	2020	International Journal of Pharmacognosy and Phytochemical Research	India	PubMed
Chaurasia et al.	2024	Vigyan Varta	India	Google Scholar
Clayton and Ritzman	2006	Veterinary Clinics of North America: Exotic Animal Practice	USA	PubMed
Crouch	2009	Acupuncture in medicine: Journal of the British Medical Acupuncture Society	Africa	PubMed
Devanand	2019	The Indian Veterinary Journal	India	EBSCOhost
Gündüz et al.	2009	Acta Veterinaria Eurasia	Turkey	PubMed
Harcourt-Brown	1996	Journal of Avian Medicine and Surgery	England	PubMed
Honnas et al.	1993	Journal of the American Veterinary Medical Association	USA	Google Scholar
Idrıs	2022	FUDMA Journal of Agriculture and Agricultural Technology	Nigeria	Google Scholar
Jos	2020	International Journal of Current Microbiology and Applied Sciences	India	Google Scholar
Joy and Divya	2014	Bangladesh Journal of Veterinary Medicine	India	EBSCOhost
Palanivelrajan et al.	2018	The Indian Veterinary Journal	India	PubMed
Palanivelrajan et al.	2022	The Indian Veterinary Journal	India	PubMed
Singh et al.	2017	International Journal of Current Microbiology and Applied Sciences	India	Google Scholar
Thangamani et al.	2024	International Journal of Veterinary Sciences and Animal Husbandry	India	PubMed
Ukaha and Okebaram	2021	Journal of Sustainable Veterinary & Allied Sciences	Nigeria	PubMed

Table 2. Distribution of the birds species and numbers that presented oviduct impaction in the analyzed literature

Author	Species	Number of patient
Amin et al., 2019	*Melopsittacus undulatus*	1
Anderson et al., 2018	*Aratinga nenday, Eclectus roratus*	2
Apurva et al., 2022	*Psittacula eupatria*	1
Bel et al., 2015	*Columba livia*	1
Bharathidasan et al., 2019	*Gallus gallus domesticus*	1
Chaudhari et al., 2020	*Melopsittacus undulatus*	1
Chaurasia et al., 2024	*Psittacula eupatria*	1
Clayton and Ritzman, 2006	*Nymphicus hollandicus*	1
Crouch, 2009	*Sphrenicus demursus*	1
Devanand, 2019	*Columba livia domesticus*	1
Gündüz et al., 2019	*Agapornis comprise*	1
Harcourt-Brown, 1996	*Nymphicus hollandicus, Eclectus roratus vosmae*	3
Honnas et al., 1993	*Dromaius novaehollandiae*	3
Idrıs, 2022	*Gallus gallus domesticus*	1
Jos, 2020	*Gallus domesticus*	1
Joy and Divya, 2014	*Gallus gallus domesticus*	2
Palanivelrajan et al., 2018	Unclear (Silky bird)	1
Palanivelrajan et al., 2022	*Psittacula eupatria*	1
Singh et al., 2017	*Anas platyrhynchos domesticus*	1
Thangamani et al., 2024	Aseel hen	1
Ukaha and Okebaram, 2021	*Gallus gallus domesticus*	1

Table 3. Characteristics of study included in the systematic review of oviduct impaction diagnosed birds.

Clinical signs	Diagnostic method	Disease	Species	Age (year)	Author(s)
Anorexia, deppression, fluffed feathers, abdominal tension	Palpation	Egg binding	*Melopsittacus undulatus*	4	Amin et al., 2019
Mass on the left caudal sternum, feather loss from ventral	Ultrasound, cytology, hematologic test	Herniated oviduct containing a non-mineralized egg.	*Aratinga nenday*	18	Anderson et al., 2018
Subcutaneous coelomic mass, pododermatitis	Hematologic test, coelomic computed tomography (CT)	Herniated oviduct	*Eclectus roratus*	12	Anderson et al., 2018
Labored breathing and tail wagging	Palpation, radiography	Egg binding	*Psittacula eupatria*	1.5	Apurva et al., 2022
No clinical signs	radiography	Egg binding	*Columba livia*	unknown	Bel et al., 2015
Cloaca with intermittent staining	Palpation, radiography, hematologic test	Egg binding	*Gallus gallus domesticus*	unknown	Bharathidasan et al., 2019
Tail wagging, swelling on abdomen	Palpation, radiography	Egg binding	*Melopsittacus undulatus*	1	Chaudhari et al., 2020
Anorexia, labored breathing, swelling on abdomen	Palpation	Egg binding	*Psittacula eupatria*	2	Chaurasia et al., 2024
Coelomic mass, widened, flaccid, erythematous vent	Radiography, hematologic test	Egg binding	*Nymphicus hollandicus*	6	Clayton and Ritzman, 2006
Unable to walk	radiography	Egg binding	*Sphrenicus demursus*	1	Crouch, 2009
Swelling on abdomen	Palpation, radiography	Egg binding	*Columba livia domesticus*	1	Devanand, 2019
No clinical signs	radiography	Egg binding	*Agapornis comprise*	1.3	Gündüz et al., 2019
Distended abdomen	Palpation	Egg binding	*Nymphicus hollandicus*	4	Harcourt-Brown, 1996
Distended abdomen	Palpation	Egg binding	*Nymphicus hollandicus*	5	Harcourt-Brown, 1996
Distended abdomen	Palpation, radiography	Egg binding, tortion of oviduct	*Nymphicus hollandicus*	Unknown	Harcourt-Brown, 1996
Lethargy, anorexia, abdominal mass	Palpation, radiography	Egg binding	*Dromaius novaehollandiae*	Unknown	Honnas et al., 1993
Lethargy, anorexia, abdominal mass	Palpation, radiography	Egg binding	*Dromaius novaehollandiae*	Unknown	Honnas et al., 1993
Lethargy, anorexia, abdominal mass	Palpation, radiography	Egg binding	*Dromaius novaehollandiae*	Unknown	Honnas et al., 1993
Staining, swelling on abdomen and anorexia	Palpation	Egg binding	*Gallus gallus domesticus*	<1	Idrıs, 2022
Weakness	Palpation, radiography	Egg binding	*Gallus domesticus*	<1	Jos, 2020
Lethargy, abdominal mass	Palpation	Egg binding	*Gallus gallus domesticus*	<1	Joy and Divya, 2014
Lethargy, abdominal mass	Palpation	Egg binding	*Gallus gallus domesticus*	<1	Joy and Divya, 2014
Distended abdomen, deppression, tail wagging	Palpation, radiography	Egg binding	Unclear (Silky bird)	2	Palanivelrajan et al., 2018
Labored breathing, tail wagging, distended abdomen	Palpation, radiography	Egg binding	*Psittacula eupatria*	3	Palanivelrajan et al., 2022
Anorexia, depression	Palpation	Egg binding	*Anas platyrhynchos domesticus*	2	Singh et al., 2017
Distended abdomen, depression	Palpation, radiography	Egg binding	Aseel hen	1	Thangamani et al., 2024
Lethargy, anorexia, abdominal mass	Palpation	Egg binding	*Gallus gallus domesticus*	<1	Ukaha and Okebaram, 2021

Table 4. Intervention characteristics for oviduct impaction, and incidence of prolapse cloaca following egg removal

Treatment	Prolapse occure	Post-treatment prescription	Author
Manual transcloacal remove	+	Antibiotic, multivitamin, calcium supplementation	Amin et al., 2019
Surgical treatment	-	Antibiotic, analgesic, Leuprolide acetate	Anderson et al., 2018
Surgical treatment	-	Antibiotic, analgesic	Anderson et al., 2018
Manual transcloacal remove	-	Antibiotic, multivitamin, analgesic	Apurva et al., 2022
Surgical treatment	-	Antibiotic, analgesic	Bel et al., 2015
Surgical treatment	-	ntibiotic, multivitamin, calcium supplementation , cortisol,	Bharathidasan et al., 2019
Manual transcloacal remove	-	Analgesic, calcium	Chaudhari et al., 2020
Manual transcloacal remove	-	Antibiotic, analgesic	Chaurasia et al., 2024
Surgical treatment	-	Antibiotic, analgesic, calcium, Leuprolide acetate	Clayton and Ritzman, 2006
Surgical treatment	-	Antibiotic, analgesic	Crouch, 2009
Surgical treatment	-	Antibiotic, analgesic	Devanand, 2019
Surgical treatment	-	Unknown	Gündüz et al., 2019
Surgical treatment	-	Unknown	Harcourt-Brown, 1996
Surgical treatment	-	Unknown	Harcourt-Brown, 1996
Surgical treatment	-	Unknown	Harcourt-Brown, 1996
Surgical treatment	-	Unknown	Honnas et al., 1993
Surgical treatment	-	Unknown	Honnas et al., 1993
Surgical treatment	-	Unknown	Honnas et al., 1993
Manual transcloacal remove	-	Antibiotic, calcium	Idrıs, 2022
Manual transcloacal remove and Surgical treatment	-	Antibiotic	Jos, 2020
Manual transcloacal remove	+	Antibiotic	Joy and Divya, 2014
Manual transcloacal remove	-	Antibiotic	Joy and Divya, 2014
Manual transcloacal remove	-	Unknown	Palanivelrajan et al., 2018
*Medical Treatment	-	Unknown	Palanivelrajan et al., 2022
Manual transcloacal remove	+	Antibiotic, calcium	Singh et al., 2017
Manual transcloacal remove	-	Antibiotic, analgesic, calcium	Thangamani et al., 2024
Surgical treatment	-	Antibiotic, analgesic	Ukaha and Okebaram, 2021

*orally calcium and cloacal paraffin liquid

Table 5. Manuel Transcloacal Removing Technic Characteristics

Species	Lubricant or local anesthetic	General Anesthesia	Author
Melopsittacus undulatus	Lignocaine HCl (2%) jelly	No	Amin et al., 2019
Psittacula eupatria	Lignocaine HCl (2%) jelly	No	Apurva et al., 2022
Melopsittacus undulatus	Liquid parafine	No	Chaudhari et al., 2020
Psittacula eupatria	Liquid parafine and lignocaine HCl (2%) jelly	No	Chaurasia et al., 2024
Gallus gallus domesticus	lignocaine HCl (2%) jelly	No	Idrıs, 2022
Gallus domesticus	Unknown lubricant	*Yes	Jos, 2020
Gallus gallus domesticus	Lignocaine HCl (2%) infiltration	**Yes	Joy and Divya, 2014
Gallus gallus domesticus	Lignocaine HCl (2%) infiltration	No	Joy and Divya, 2014
Unclear (Silky bird)	Liquid parafine	No	Palanivelrajan et al., 2018
Anas platyrhynchos domesticus	Lignocaine HCl (2%) jelly	No	Singh et al., 2017
Aseel hen	Liquid parafine and lignocaine HCl (2%) jelly	No	Thangamani et al., 2024

* Xylazine and Ketamine hydrochloride intamuscular. ** Ketamine hydrochloride intamuscular.

Table 6. Prognosis of patients after treatment

Species	Follow-up period	Result	Author
Melopsittacus undulatus	unknown	unknown	Amin et al., 2019
Aratinga nenday	5.5 years	No complication	Anderson et al., 2018
Eclectus roratus	18 months	No complication	Anderson et al., 2018
Psittacula eupatria	unknown	unknown	Apurva et al., 2022
Columba livia	unknown	unknown	Bel et al., 2015
Gallus gallus domesticus	30 days	No complication	Bharathidasan et al., 2019
Melopsittacus undulatus	unknown	unknown	Chaudhari et al., 2020
Psittacula eupatria	unknown	unknown	Chaurasia et al., 2024
Nymphicus hollandicus	73 days	No complication	Clayton and Ritzman, 2006
Sphrenicus demursus	18 months	No complication	Crouch, 2009
Columba livia domesticus	3 weeks	No complication	Devanand, 2019
Agapornis comprise	Unknown	Unknown	Gündüz et al., 2019
Nymphicus hollandicus	Unknown	Unknown	Harcourt-Brown, 1996
Nymphicus hollandicus	Unknown	Unknown	Harcourt-Brown, 1996
Nymphicus hollandicus	Unknown	Unknown	Harcourt-Brown, 1996
Dromaius novaehollandiae	6 months	No complication	Honnas et al., 1993
**Dromaius novaehollandiae*	2 months	Reoperation (hysteretomy)	Honnas et al., 1993
Dromaius novaehollandiae	1 month	Salphingitis	Honnas et al., 1993
Gallus gallus domesticus	Unknown	Unknown	Idrıs, 2022
Gallus domesticus	Unknown	Unknown	Jos, 2020
Gallus gallus domesticus	Unknown	Unknown	Joy and Divya, 2014
Gallus gallus domesticus	Unknown	Unknown	Joy and Divya, 2014
Unclear (Silky bird)	Unknown	Unknown	Palanivelrajan et al., 2018
Psittacula eupatria	Unknown	Unknown	Palanivelrajan et al., 2022
Anas platyrhynchos domesticus	Unknown	Unknown	Singh et al., 2017
Aseel hen	Unknown	Unknown	Thangamani et al., 2024
Gallus gallus domesticus	2 weeks	No complication	Ukaha and Okebaram, 2021

*After reoperation 5 months later bird was clinically normal.

Egg binding was the cause most frequently diagnosed through radiographic analysis and exploratory surgery in birds suffering from oviduct impaction. Hernia and torsion of oviduct was reported in three cases. In the analyzed articles, the range of ages was from one to 18 years. Four cases documented individuals younger than one year.

Results showed that surgical treatment (n=16/27) was mainly used for oviduct impaction, followed by manual transcloacal removal (n=11/27), and medical treatment (n=1/27). In one case, two eggs were present, and more than one method was presented because one of the eggs was removed manually, and the other was removed surgically. The analyzed study documented that prolapsus occurred following manual removal of the egg in three cases. In the manual transcloacal removal technique, two cases were reported to have used general anesthesia (Table 4). Nine authors in the reviewed studies did not provide information on post-intervention prescription. Other authors generally focused on antibiotics, calcium, and analgesics. Two authors also emphasized the importance of suppressing the ovarian activity with leuprolide acetate treatment. All the authors highlighted that lubricant or anesthetic jelly drugs help to remove the egg (Table 5).

According to the ten authors who followed the patients, no complications were observed during the follow-up period. In a study conducted by Honnas et al. (1993), two cases of complications arose following egg removal. The prognosis of patients described in Table 6 is discussed in detail.

Discussion

The unique anatomy and physiology of the avian reproductive tract result in a highly productive yet poorly accessible organ system. Affected birds are commonly presented with nonspecific lethargy, anorexia, coelomic swelling, and sometimes lay abnormal eggs (Echols and Speer, 2022; Vavlas et al., 2024).

The oviduct can be divided into five portions: infundibulum, magnum, isthmus, uterus, and vagina. An impaction may occur in one or all portions. The diagnosis of egg binding should be based on clinical signs, physical examination, and radiography. Suspicion should arise if the clinician is presented with a female bird with distended coelom and tenesmus (Harcourt-Brown, 1996; Orosz et al., 1997). Other signs might include abdominal swelling, tail wagging, or respiratory difficulty. We believe that pododermatitis, noted in a single case reported by Anderson et al. (2018), was related to the conditions of care. In cases where the eggshell is formed, palpation is sufficient for diagnosis. When diagnosis is not possible, the authors recommend using ultrasound, radiography, or tomography. Although blood tests were utilized in four cases, we believe they serve as an auxiliary diagnostic method for oviduct impaction. It is important to note that blood tests are particularly valuable for diagnosing dystocia caused by hypocalcemia or for obtaining information about the patient's condition.

A treatment protocol for oviduct impaction must be designed for clinical signs, patient condition, and etiology (Harcourt-Brown, 1996). This study proposes protocol focused on supplemental treatment, analgesia , and minimizing complications through antibiotics after egg removal or salpingohysterectomy. The study reported that no infection-related complications were observed in the follow-up of 7 cases who were prescribed antibiotics after the intervention. We recommend that patients be followed up annually to gather more accurate data.
The analyzed studies showed that surgical treatment (n=16/27) was mainly used for oviduct impaction. For surgical treatment, a common approach is a ventral midline approach (Vavlas et al., 2024).
There is little information on oviductal impaction and management of egg binding in wild birds. In the study, we analyzed cases where no reports were found in wild birds. Further studies are needed to classify the different presentations of reproductive diseases in female birds. Prospective studies with frequent and defined follow-up are required to assess therapeutic options and prognosis for birds with oviductal disease.

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Conflict of Interest

The authors declared that there is no conflict of interest.

Author Contribution Statement

K.G.Ö.: Methodology, data collection, writing manuscript
D.S.: Supervision, conceptualization, methodology, review and editing

Ethical Approval

Due to the non-experimental-inducted case reports, the present study was not subject to approval by the Ethical Committee.

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ID: 596

Phytochemical and Antioxidative Properties of *Kaempferia* Species Found in Bangladesh

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Abstract

The genus *Kaempferia* (Zingiberaceae) comprises medicinally significant species widely utilized in traditional medicine for their diverse bioactive compounds and therapeutic potential. This study systematically investigates the phytochemical composition, antioxidant capacity, and pigment profile of the rhizomes of five *Kaempferia* species indigenous to Bangladesh. The total phenolic content (TPC) and total flavonoid content (TFC) were quantified, while antioxidant activity was assessed using DPPH and FRAP assays from the methanolic extract of rhizome. Additionally, major pigments, including chlorophyll a, chlorophyll b, total chlorophyll (a+b), and total carotenoids, were analyzed from the leaf extract. Among the studied species, *K. pulchra* exhibited the highest TPC (14.45 mg GAE/g) and TFC (31.31 mg QE/g), whereas *K. angustifolia* demonstrated the strongest DPPH radical scavenging activity (153.1 mg/mL) and the highest FRAP value (910.01 µM Fe^{2+}/L), indicating superior antioxidative potential. Conversely, *K. galanga* exhibited the lowest antioxidant activity (186.5 mg/mL DPPH and 50.23 µM Fe^{2+}/L FRAP). Pigment analysis revealed that *K. rotunda* contained the highest concentrations of chlorophyll a (0.60 mg/g FW), chlorophyll b (0.70 mg/g FW), and total chlorophyll (1.30 mg/g FW), while *K. parviflora* exhibited the highest total carotenoid content (0.15 mg/g FW). These findings underscore the considerable antioxidative and pharmacological potential of *K. pulchra* and *K. angustifolia*, highlighting their suitability for applications in herbal medicine and pharmaceutical formulations. Further investigations into their bioactive compounds and mechanistic pathways could facilitate their integration into evidence-based therapeutics.

Keywords: *Kaempferia, Medicinal potential, Antioxidant, TPC, TFC.*

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Native Chicken of the Black Sea Region: Trabzon Gugullisi

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Abstract

Chicken breeds account for 63% of all bird species worldwide, representing a significant proportion. The global chicken population is approximately 2.5 times larger than the human population, with the majority of chickens concentrated in Asia, Latin America, and the Caribbean. Europe and the Caucasus account for 13% of the world's chicken population, while Africa follows with 7%. Local breeds represent a significant portion of global poultry genetic diversity. Domestic chicken breeds have developed traits such as broad ecological adaptation, disease resistance, and economic efficiency during evolutionary processes and expansion. However, the widespread use of commercial chicken breeds has caused a substantial reduction in local poultry genetic resources, threatening the genetic diversity of local breeds. In this context, the most effective way to preserve biodiversity is by conserving native chicken breeds. In Turkiye, although only two native chicken breeds Denizli and Gerze are officially recognized, there are many locally adapted chicken breeds, like the Trabzon Gugullisi, which have developed over many years in our region. The Trabzon Gugullisi is known for its high egg production and meat yield, while also being considered a decorative breed due to its visual appeal. Characteristically, it has a bony protrusion on its head, a trait that is also observed in its chicks. Additionally, it is notable for its upright and majestic walk. The aim of this study is to describe the Trabzon Gugullisi chickens and to provide a scientific basis for conservation and breeding efforts of this native breed.

Key Words: *Trabzon Gugullisi, Native chicken breeds, Biological conservation, Biodiversity, Chicken genetics*

Karadeniz Bölgesinin Yerel Tavuğu: Trabzon Gugullisi

Özet

Tavuk ırkları, dünyadaki tüm kuş türlerinin %63'ünü oluşturarak büyük bir orana sahiptir. Dünya genelindeki tavuk sayısı, insan nüfusunun yaklaşık 2,5 katıdır ve bu tavukların büyük bir kısmı Asya, Latin Amerika ve Karayipler'de yoğunlaşmıştır. Avrupa ve Kafkaslar ise dünya tavuk nüfusunun %13'ünü oluştururken, Afrika bu oranı %7 ile takip etmektedir. Yerli ırklar, dünya çapındaki kanatlı genetik çeşitliliğinin önemli bir kısmını temsil etmektedir. Evcil tavuk ırkları, evrimsel süreçler ve genişleme sırasında geniş ekolojik adaptasyon, hastalık direnci ve ekonomik verimlilik gibi özellikler geliştirmiştir. Ancak, ticari tavuk ırklarının yaygınlaşması, yerel tavuk genetik kaynaklarında büyük azalmalar yaratmış ve bu durum, yerel ırkların genetik çeşitliliğinin tehdit altına girmesine yol açmıştır. Bu bağlamda, biyolojik çeşitliliğin korunmasının en etkili yolu, yerel tavuk ırklarının korunmasıdır. Ülkemizde Denizli ve Gerze olmak üzere yalnızca 2 yerli tavuk ırkı tescillenmiş olmasına rağmen, Trabzon Gugullisi gibi coğrafyamıza özgü ve uzun yıllar adaptasyon geliştirmiş pek çok yerel tavuk ırkı mevcuttur. Trabzon Gugullisi, yüksek yumurta verimi ve karkas et oranıyla dikkat çekerken, aynı zamanda görsel olarak süs tavuğu kategorisinde değerlendirilebilecek güzellikte bir ırktır. Karakteristik olarak kafasında bir kemik çıkıntısına sahiptir ve bu özellik civcivlerinde de gözlemlenmektedir. Ayrıca, dik ve heybetli yürüyüşleri ile dikkat çekmektedir. Bu bildirinin amacı, Trabzon Gugullisi tavuklarını tanıtmak ve bu yerli ırkın korunması ile ıslahına yönelik çalışmalara bilimsel bir temel oluşturmaktır.

Anahtar Kelimeler: *Trabzon gugullisi, yerli tavuk ırkları, biyolojik koruma, biyoçeşitlilik, tavuk genetiği*

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Bioactivities of *Thymbra spicata*: Exploring its Cytotoxic, Antibacterial and Antiviral Activities

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Abstract

Thymbra spicata, locally known as zahter, is a medicinal plant-rich in bioactive compounds, including phenolic compounds, flavonoids, and essential oils. *T. spicata* is used to regulate blood sugar levels and digestive system, strengthen immunity, improve memory, be calm, and care for the skin. It is known to have remarkable antibacterial, antifungal, antioxidant, and insecticidal activities. The aim of this study was to investigate the cytotoxic, antibacterial, and antiviral activities of *T. spicata* ethanol extract. Firstly, ultrasound-assisted extraction was performed using 70% ethanol. Then, total phenolic and total flavonoid contents were determined. The cytotoxic activity was assessed against lung adenocarcinoma (A-549), breast adenocarcinoma (MDA-MB-231), breast adenocarcinoma (MCF-7), prostate cancer (PC-3), and neuroblastoma (SH-SY5Y) cell lines using the MTT assay to determine cell viability and IC_{50} values. Antibacterial activity was tested against *Escherichia coli* and *Staphylococcus aureus* using the disk diffusion and minimum inhibitory concentration methods. The antiviral potential was evaluated *in ovo* against infectious bronchitis virus. Herein, total phenolic content was measured as 31.84±0.09 mg GAE/g, total flavonoid content as 5.42±0.13 mg CE/g. MTT assay revealed dose-dependent cytotoxicity to all cell lines. IC_{50} values were found as 335.78±39.10 µg/ml for A549, 592.18±20.83 µg/ml for MDA-MB-231, 473.00±27.52 µg/ml for MCF-7, 308.99±31.51 µg/ml for PC-3, and 370.668±11.85 µg/ml for SH-SY5Y cell lines. The zone diameter was measured as 8.19 mm for *S. aureus*, and 7.12 mm for *E. coli*, demonstrating antibacterial potential of *T. spicata*. In addition, MIC values were 6.25 mg/ml and 12.5 mg/ml for *S. aureus* and *E. coli*, respectively. The antiviral activity of the extract was determined between 125-500 µg/ml concentrations, indicating promising inhibitory effects. These findings highlight the potential of *T. spicata* as a natural source of bioactive compounds for biomedical and pharmaceutical applications. Further studies are needed to identify its active components and elucidate its mechanism of action.

Key Words: *Thymbra spicata, zahter, cytotoxic, antibacterial, antiviral*

ID: 599

Patates Mini Yumru Üretiminde Akan Su Kültürü, Aeroponik ve Topraklı Ortam Yöntemlerinin Verim ve Verim Unsurları Yönleriyle Karşılaştırılması

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Özet

Patateste meristem kültüründen elde edilen fidelerden süper elit kademede mini yumru üretiminde geleneksel topraklı yetiştiriciliğin yanı sıra sağladığı avantajlar nedeniyle son yıllarda aeroponik yöntemlerde kullanılmaya başlanmıştır. Ülkemizde sertifikalı tohumluk üretimi ise ithalat yoluyla başta Hollanda ve Almanya'dan getirilen çoğunlukla orijinal kademedeki tohumluklarla yapılmaktadır. Son yıllarda yapılan çeşit geliştirme çalışmaları neticesinde 2025 yılı itibari ile tescil edilen çeşit sayısı 47 olmuştur (TTSM 2025). Patates tohumluğunda dışa bağımlılığı azaltmak için özellikle yerli çeşitlerimize ait tohumluk üretimimizi arttırmamız gerekmektedir. Patates mini yumru üretiminde topraklı yetiştiriciliğin dışında daha avantajlı olan hidroponik sistemlerle daha fazla üretim yapılabilir.

Araştırmada elde edilen verilerin istatistiki analizleri sonucunda geleneksel topraklı üretime göre hidroponik üretim sistemlerinden akan su kültürü ve aeroponik sistemle mini yumru üretiminin daha avantajlı olduğu tespit edilmiştir. 2021 ve 2022 yılları ortalamasında Nigşah, Leventbey ve Onaran 2015 çeşitlerinden aeroponik sistemde 32 adet, akan su kültürü sisteminde 29,3 adet ve topraklı yetiştiricilikte ise bitki başına ortalama 5,3 adet mini yumru elde edilmiştir. Bitki başına ortalama mini yumru sayısı açısından topraklı yetiştiricilik, aeroponik sistem ve akan su kültürü sistemi ile yetiştiriciliğin çok gerisinde kalmıştır.

***Anahtar Sözcükler**:* Patates, Mini Yumru, Akan su kültürü, Aeroponik, Topraklı Ortam, Doku Kültürü

Comparison of Flowing Water Culture, Aeroponic and Soil Media Methods in terms of Yield and Yield Elements in Potato Mini Tuber Production

Abstract

In potato, in the production of mini tubers in the super elite stage from seedlings obtained from meristem culture, in addition to traditional soil cultivation, aeroponics methods have started to be used in recent years due to the advantages they provide. In our country, certified seed production is carried out with mostly original stage seeds brought from the Netherlands and Germany through import. In order to reduce external dependency in potato seeds, we need to increase our seed production, especially of our local varieties. In potato mini tuber production, more production can be made with hydroponic systems, which are more advantageous than traditional soil cultivation. For this reason, studies are needed to increase the production of mini tubes in the super elite stage, which constitutes the beginning of seed production in potatoes.

In this study, the yield and yield elements of super elite stage mini tuber production, which is the first stage of potato seed production in flowing water culture, aeroponics and soil cultivation, were examined and which method was more advantageous was determined.

***Keywords**:* Potato, mini tuber. flowing water culture, aeroponik, grounded environment, tissue culture

1. Giriş

Patateste meristem kültüründen elde edilen bitkilerle süper elit kadem mini yumru üretimi, topraklı yetiştiriciliğin yanı sıra son yıllarda avantajları nedeniyle aeroponik yöntemlerle de yetiştiricilik yapılmaktadır. Ülkemizde ise sertifikalı tohumluk üretimi,Avrupa ülkelerinden genellikle orijinal kademedeki tohumlukların ithalatı yoluyla gerçekleştirilmektedir. Son yıllarda yapılan çeşit geliştirme çalışmaları neticesinde 2025 yılı itibari ile tescil edilen çeşit sayısı 47 olmuştur (TTSM 2025). Patates tohumluğu üretiminde dışa bağımlılığı azaltmak amacıyla son yıllarda ülkemizde geliştirilen çeşitlerimizin tohumluk üretiminin artırılması büyük önem taşımaktadır. Mini yumru üretiminde topraklı yetiştiriciliğin dışında, hidroponik sistemler gibi daha verimli yöntemlerle üretim artırılabilir. Bu nedenle, patates tohumluğu üretiminin temelini oluşturan süper elit kademedeki mini yumru üretiminin arttırılması konusunda daha fazla araştırma ve çalışma yapılması gerekmektedir.

2. Materyal ve Metot

2.1 Materyal

Araştırmalar 2020-2023 yılları arasında Patates Araştırma Enstitüsü Müdürlüğü doku kültürü laboratuvarında ve tam kontrollü serasında yürütülmüştür.

Araştırmada Onaran 2015, Leventbey, Nigşah çeşitleri kullanıldı. Aşağıdaki çizelgede çeşitlerin genel özellikleri verilmiştir.

Çizelge 1. Denemede kullanılan çeşitlerin özellikleri

Çeşit	Özellik	Olgunluk	Verim Ortalaması kg/da	Kuru madde içeriği (%)	Nişasta içeriği (%)
ONARAN 2015	Yemeklik	Geççi	5.487	18,8-20,1	12,7-13,9
NİĞŞAH	Yemeklik	Orta Erkenci	4.900	19,0-21,0	13,0-15,0
LEVENBEY	Yemeklik	Orta Erkenci	5.523	19,2-19,8	13,1-13,6

2.2 Metot

Çalışmada 2 farklı deneme yürütüldü.

2.2.1. Akan Su Kültürü, Aeroponik ve Topraklı Ortam Karşılaştırma Denemeleri; 2021-2022 yıllarında, Su Kültürü, Aeroponik ve Topraklı Ortam yöntemleri üzerine yapılan denemeler, tesadüfi parsellerin kullanıldığı bir deneme desenine göre gerçekleştirilmiştir. Denemeler, iki yıl boyunca her biri 4 tekerrürlü olarak kurulmuştur. Ana parsellerde uygulamalar, alt parsellerde ise farklı çeşitler üzerinde çalışılmıştır. Sıra arası mesafe 10 cm, sıra üzeri mesafe ise 20 cm olacak şekilde, her metrekareye 50 bitki dikilmiştir.

2.2.2. Akan Su Kültürü, Aeroponik ve Topraklı Ortam Denemelerinden Elde Edilen Farklı Boyuttaki Yumruların Verim ve Verim Unsurları Yönünden Karşılaştırılması Denemeleri;

2022 ve 2023 yıllarında, 10-30 mm ve 30 mm'den büyük boyutlardaki mini yumrular kullanılarak, tül seralarda çift sıralı bir tarla denemesi kurulmuştur. Denemede, sıra arası 70 cm, sıra üzeri ise 20 cm olarak belirlenmiş ve her sırada 25 yumru olacak şekilde bir düzenleme yapılmıştır. Çalışmalar, her iki yıl için tesadüf blokları deneme desenine uygun olarak faktöriyel deneme düzeniyle, 4 tekerrürle gerçekleştirilmiştir.

Akan Su Kültürü:

Akan su kültürü sistem, her bir kanal 300 cm uzunluğunda, 5 cm yüksekliğinde, 10 cm genişliğinde kanallardan oluşturuldu. m^2' ye 50 bitki yerleştirildi. Besin solüsyonu, bir 3000-L tanktan 2.5 L / dk'lık bir hızda bir dalgıç pompa kullanılarak kanalın girişine pompalandı, daha sonra besin solüsyonu kanalın giriş ucundan 2 cm daha düşük olan kanalın karşı ucuna doğru besin tankına geri çekildi. Bitkicikler, bitki örtüsünü desteklemek için hidroponik sisteme köpüklerle monte edildi. Aynı kanalda yetiştirilen bitkiler aynı muameleye tabi tutuldu ve besin çözeltisinin konsantrasyonu tam olarak sağlandı. Makro besinler için; kalsiyum süper fosfat, potasyum nitrat, amonyum nitrat. Mikro besinler için; bakır sülfat, çinko sülfat, amonyum molibdat, borik asit, mangan sülfat, magnezyum sülfat, demir-EDTA besinleri kullanıldı (Farran ve ark. 2006). Vejetasyon süresi boyunca bitkinin gelişimine göre besin çözeltisi tankındaki çözelti yenilendi.

Aeroponik Sistem: 8 m boyunda 1 m eninde 1 m yüksekliğindeki tezgahlar metal profil iskelet üzerine straforla kaplandı. Tezgahların üstüne konulacak siyaha boyanmış polikarbonlara 10*20 cm dikim sıklığında m^2' ye 50 bitki yerleştirildi. Her bir masaya besleme borusu boyuna 2' şer adet 8 m uzunluğunda borular ve her bir tezgaha ana besleme borusuna 360° dereceli 1 m aralıklarla aeroponik püskürteçler ile sisleme yapıldı. Sistemde besin tankı ve drenaj sistemi kullanıldı. Bitkilerin gelişim durumlarına göre besin çözeltisi tankındaki çözelti yenilendi.

Topraklı Ortam: Topraklı yetiştiricilikte in vitro koşullarda yetiştirilen bitkiler saksılara aktarıldı. Yetiştirme ortamı olarak steril torf kullanıldı. Bitki çeşitleri bir sıraya 30 bitki gelecek şekilde her bir saksıya 20 cm aralıklı olacak şekilde 2 bitki yerleştirildi.

Akan su kültürü, aeroponik ve topraklı yetiştiricilikte bitkilerin hasadı farklı zamanlarda yapıldı. Akan su kültürü ve aeroponik yöntemde sıralı hasat yapılırken, topraklı yetiştiricilikte ise hasat olgunluğuna gelen bitkiler tek seferde hasat edildi. Hasat edilen mini yumrular tül seralarda dikim tarihine kadar iklimlendirme dolabında +4 °C 'de muhafaza edildi.

3. Bulgular

3.1. Bitki Başına Mini Yumru Sayısı(adet/bitki):

2021 yılında denemeye alınan patates çeşitlerinin bitki başına yumru sayısına çeşit, metot ana etkisi ile çeşitxmetot interaksiyonu ortalama değerler bakımından istatistiki olarak önemli bulunmuştur (Çizelge 2). Çizelge 2' de görüldüğü gibi denemede kullanılan çeşitlerin m^2 deki mini yumru sayıları akan su kültürü sistemindeki Leventbey çeşidi bitki başına 42,9 adet ile a grubunda ilk sırada, aeroponik sistemde Niğşah çeşidi 38,1 adet ile b grubunda ikinci sırada, yine aeroponik sistemde 30,5 adet ile Onaran 2015 çeşidi c grubunda üçüncü sırada yer almışlardır. Topraklı yetiştirme ortamında Niğşah çeşidi ise 3,9 adet ile h grubunda son sırada yer almıştır. Bitki başına ortalama mini yumru sayıları açısından topraklı ortamda yetiştiricilik, aeroponik sistem ve akan su kültürü sistemi ile yetiştiriciliğin çok gerisinde kalmıştır.

2022 yılında denemeye alınan patates çeşitlerinin bitki başına yumru sayısına çeşit, metot ana etkisi ile çeşitxmetot interaksiyonu ortalama değerler bakımından istatistiki olarak önemli bulunmuştur (Çizelge 2). Çizelge 2' de görüldüğü gibi denemede kullanılan çeşitlerin bitki başına mini yumru sayılarında akan su kültürü sistemindeki Leventbey çeşidi bitki başına 40,7 adet ile a grubunda ilk sırada, aeroponik sistemde Niğşah çeşidi 36,4 adet ile b grubunda ikinci sırada, yine aeroponik sistemde 34,4 adet ile Leventbey çeşidi b grubunda üçüncü sırada yer almışlardır. Topraklı yetiştirme ortamında Niğşah çeşidi ise 4,2 adet ile f grubunda son sırada yer almışlardır. Bitki başına ortalama mini yumru sayıları açısından topraklı ortamda yetiştiricilik, aeroponik sistem ve akan su kültürü sistemi ile yetiştiriciliğin çok gerisinde kalmıştır.

Çizelge 2. Denemeye alınan çeşitlerin bitki başına mini yumru sayısı(adet/bitki)

Yıllar	2021				2022				2021+2022			
Çeşitler	Aeroponik Sistem	Akan Su Kültürü	Topraklı Ortam	Ortalama	Aeroponik Sistem	Akan Su Kültürü	Topraklı Ortam	Ortalama	Aeroponik Sistem	Akan Su Kültürü	Topraklı Ortam	Ortalama
Onaran 2015	30,5 c	21,3 f	6,1 g	19,3 b	28,3 c	23,8 d	6,4 f	19,5 b	29,4 c	22,6 d	6,3 e	19,4 c
Leventbey	24,5 e	42,9 a	4,3 gh	23,9 a	34,4 b	40,7 a	6,7 f	27,3 a	29,5 c	41,8 a	5,6 ef	25,6 a
Niğşah	38,1 b	27,0 d	3,9 h	23,0 a	36,4 b	19,8 e	4,2 f	20,1 b	37,2 b	23,5 d	4,1 f	21,6 b
Ortalama	31,0 a	30,4 a	4,8 b	22,1	33,0 a	28,1 b	5,8 c	22,3	32,0 a	29,3 b	5,3 c	22,2
			Çeşit	**				**				**
			Metod	**				**				**
			Çeşit*Metod	**				**				**
			LSD(%5)	2,2				3,1				2,1
			DK (%)	6,8				9,7				6,5

*:p≤0.05 ; **:p≤0.01 hata sınırları içerisinde istatistiki olarak önemli
Aynı harf grubuna giren değerler %5 önem düzeyinde birbirinden farklı değildir.

Akan Su Kültürü, Aeroponik ve Topraklı Ortam Denemelerinden Elde Edilen 10-30 mm Boyutundaki Yumruların Verim ve Verim Unsurları Yönünden Karşılaştırılması Denemeleri; 2021 yılında elde edilen 10-30 mm boyutlarındaki mini yumrularla, 25 Mayıs 2022 tarihinde tül seralarda çift sıralı bir tarla denemesi kurulmuştur. Bu denemede, sıra arası 70 cm, sıra üzeri 20 cm ve her sırada 25 yumru olacak şekilde deneme kurulmuştur. Elit yumrular 6 Ekim 2022'de hasat edilmiştir.

2022 yılında üretilen 10-30 mm boyutlarındaki mini yumrularla ise, 27 Mayıs 2023 tarihinde benzer şekilde tül seralarda çift sıralı tarla denemesi kurulmuştur. Elit yumrular 14 Ekim 2023'te hasat edilmiştir.

3.2. Tek Bitki Verimi (adet/bitki):

2022 yılında denemeye alınan patates çeşitlerinin tek bitki verimine etkilerinin çeşit ana etkisinin ortalama değerler bakımından istatistiki olarak önemli olduğu, çeşitxmetot interaksiyononun ise istatistiki olarak önemsiz olduğu belirlenmiştir (Çizelge 3). Duncan Çoklu Karşılaştırma Testinde %5 önem seviyesine göre oluşan gruplar da Çizelge 3' te verilmiştir. Topraklı ortamdan elde edilmiş mini yumru dikiminden Leventbey çeşidi bitki başına 7,3 adet elit yumru ile ilk sırada, akan su kültürü sisteminden elde edilmiş mini yumru dikiminde Nığşah çeşidi bitki başına 5,6 adet ile son sırada yer almıştır. Topraklı ortamda elde edilmiş mini yumrular daha iri sürgünler oluşturduğundan bu yumruların dikiminden daha fazla sayıda ön elit kademe yumru elde edilmiştir.

2023 yılında denemeye alınan patates çeşitlerinin tek bitki verimine etkilerinin çeşit ve metot ana etkisinin ortalama değerler bakımından istatistiki olarak önemli olduğu, çeşitxmetot interaksiyononun ise istatistiki olarak önemsiz olduğu belirlenmiştir (Çizelge 3). Duncan Çoklu Karşılaştırma Testinde %5 önem seviyesine göre oluşan gruplar da Çizelge 3' te verilmiştir. Çizelge 3' te görüldüğü gibi topraklı ortamdan elde edilmiş mini yumruların dikiminden daha fazla sayıda elit yumru elde edilmiştir.

Denemeye alınan patates çeşitlerinin iki yıl ortalamasında tek bitki verimine etkilerinin çeşit ve metod ana etkisinin ortalama değerler bakımından istatistiki olarak önemli olduğu, çeşitxmetot interaksiyononun ise istatistiki olarak önemsiz olduğu belirlenmiştir (Çizelge 3). Topraklı yetiştiricilikten elde edilmiş mini yumru dikiminden Leventbey çeşidi bitki başına 7,0 adet elit yumru ile a grubunda ilk sırada, akan su kültürü sisteminden elde edilmiş mini yumru dikiminde Nığşah çeşidi bitki başına 5,3 adet ile d grubunda son sırada yer almıştır.

Çizelge 3. Denemeye Alınan Patates Çeşitlerinin Tek Bitki Verimi Yönüyle Elde Edilen Ortalama Değerler (adet/bitki)

Yıllar	2022				2023				2022+2023			
Çeşitler	Aeroponik Sistem	Akan Su Kültürü	Topraklı Ortam	Ortalama	Aeroponik Sistem	Akan Su Kültürü	Topraklı Ortam	Ortalama	Aeroponik Sistem	Akan Su Kültürü	Topraklı Ortam	Ortalama
Onaran 2015	5,9 de	6,1 cde	6,3 b-e	6,1 b	5,3 cd	5,6 bc	5,8 bc	5,5 b	5,6 cd	5,9 bcd	6,0 bc	5,8 b
Leventbey	7,0 ab	6,9 abc	7,3 a	7,1 a	6,1 ab	5,8 bc	6,6 a	6,2 a	6,6 ab	6,3 abc	7,0 a	6,6 a
Nigşah	6,5 a-d	5,6 e	6,8 abc	6,3 b	5,2 cd	4,9 d	5,9 bc	5,3 b	5,8 bcd	5,3 d	6,4 ab	5,7 b
Ortalama	6,5 ab	6,2 b	6,8 a	6,5	5,5 b	5,4 b	6,1 a	6,5	6,0 b	5,8 b	6,5 a	6,5
		Çeşit		*				**				*
		Metod						*				*
		Çeşit*Metod										
		LSD(%5)		0,9				0,4				0,8
		DK (%)		9,1				8,7				8,5

*:p≤0.05 ; **:p≤0.01 hata sınırları içerisinde istatistiki olarak önemli
Aynı harf grubuna giren değerler %5 önem düzeyinde birbirinden farklı değildir.

4. Tartişma Ve Sonuç

Geleneksel topraklı yetiştiriciliğin yanında aeroponik ve akan su kültürü gibi modern sistemlerle de patateste mini yumru üretimi yapılmıştır. Aeroponik ve akan su kültürü yetiştiricilikte sistem kurulumunun maliyeti ve profesyonel eleman gerekliliği topraklı ortama göre dezavantaj oluşturmaktadır. Mini yumru üretiminde bitki başına yumru sayısı önemli olduğundan Topraklı Ortamla yetiştiriciliğe göre 5-6 kat daha fazla sayıda yumru elde edilen aeroponik ve akan su kültürü sistemi daha avantajlı bulunmuştur. Čížek vd. (2022) çalışmalarında buldukları bitki başına ortalama mini yumru sayısı 24 ve 41 adet, Rykaczewska (2016) 32,5 ve 36 adet, Bag vd. (2015) 38 ve 42 adet ile deneme sonuçları uyumlu bulunmuştur. Aeroponik sistemde bitki kökleri havada asılı durduğundan daha iyi havalanmakta, bu nedenle kökleri akan su kültürü sistemine göre daha sağlıklı gelişmektedir. Akan su kültürü sisteminde bitkinin yeşil aksamı diğer iki sisteme göre daha iyi gelişmiştir. Aynı çeşitlerde akan su kültürü sisteminde aeroponik sisteme göre bir hafta kadar daha geç yumru oluşturmuştur. Aeroponik ve akan su kültürü sisteminde bitkilerin vejetasyon süresi (6-7 ay) topraklı yetiştiriciliğe göre daha uzun sürmekte bu nedenle daha fazla sayıda hasada imkan sağladığından bitki başına yumru sayısı artmıştır. Akan su kültürü sisteminde su içerisinde bulunan yumruların hasadı geciktirildiğinde yumruların bir kısmında çürümeler olmuştur. Aeroponik ve akan su kültürü yöntemi ile elde edilen mini yumruların depoya alınmadan önce oda sıcaklığında kontrollü şartlarda bir hafta kadar tutulmaları depo kayıplarını azaltmıştır. Her üç sistemden elde edilen yumrular +4 ºC' de muhafaza edildiklerinde topraklı yetiştirme ortamından elde edilen mini yumruların daha erken sürgün oluşturdukları tespit edilmiştir. Aeroponik ve akan su kültürü sistemlerinden elde edilen mini yumruların 6-8 ºC' de dikime kadar muhafaza edilmeleri daha uygun olacağı tespit edilmiştir. Leventbey çeşidinin akan su kültürü sistemine daha uyumlu olduğu tespit edilmiştir. Her üç yöntemden elde edilen mini yumruların araziye dikimlerinde bitki çıkışlarında bir problem tespit edilmemiştir. Yumruların araziye dikimlerinde bitkilerin çıkış sürelerinde ve bitki başına elit yumru sayısında mini yumru yetiştiricilik metodunun %5 önem seviyesinde etkisinin olduğu tespit edilmiştir. Patateste mini yumru yetiştirme metotlarından akan su kültürü ve aeroponik sistemleri kendi aralarında kıyasladığımızda bitki başına verimlerinin yanında özellikle depo kayıplarının daha az olmasından dolayı aeroponik sistem daha avantajlı bulunmuştur.

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Effect of synthetic insecticides and botanical extract against whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) in different okra varieties

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Abstract

The whitefly, *Bemisia tabaci*, is a major pest of okra (*Abelmoschus esculentus*), causing significant yield losses. Therefore this study was designed to evaluate the population dynamics of *B. tabaci* and the efficacy of synthetic insecticides and neem seed extract in different okra varieties during 2024. In the first experiment, the population trend of *B. tabaci* was monitored in five okra varieties: Marvi, Viraj, Sabz Pari, Green Finger, and Advanta. In this experiment, the infestation started in late May, peaked in late July (6.21 whiteflies per leaf), and declined by early September. Green Finger exhibited the lowest infestation (2.08 whiteflies per leaf), while Viraj had the highest (4.05 whiteflies per leaf). Green Finger also recorded the highest yield (6064.4 kg/ha), whereas Viraj had the lowest (1834.8 kg/ha). In the second experiment, synthetic insecticides (Cypermethrin and Acetamiprid) and neem seed extract were evaluated. Acetamiprid was the most effective, reducing *B. tabaci* populations to 1.58 and 1.56 whiteflies per leaf after the first and second sprays, respectively. Neem seed extract also suppressed whitefly populations (4.79 and 4.84 whiteflies per leaf). Acetamiprid resulted in the highest yield (2984 kg/ha) and cost-benefit ratio (26.52), followed by Cypermethrin (22.26) and neem seed extract (19.69). Green Finger showed higher resistance to *B. tabaci*, while Acetamiprid and neem seed extract effectively reduced infestation. The study concluded that these treatments should be integrated into pest management strategies to improve okra productivity.

Key Words: *Bemisia tabaci, Okra, Insecticides, Neem seed extract, Pest management*

ID: 602

Lethal and sublethal effects of neem leaves extract (*Azadirachta indica)* against pink hibiscus mealy bug (*Maconellicoccus hirsutus*) (Hemiptera: Psudococcidae)

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Abstract

Maconellicoccus hirsutus, commonly known as the pink hibiscus mealybug, is a polyphagous insect pest with a global presence, posing significant economic and ecological threats to a wide range of host plants. This study evaluated the lethal and sub lethal effects of neem (*Azadirachta indica*) leaves extract against *Maconellicoccus hirsutus* under laboratory conditions. Adult female's *M. hirsutus* were treated with dilutions of neem leaves and the greatest mortality (54%) was observed at 5% neem leaves extract after 72 hours, while no mortality was recorded in the control after 72 hours. The LC_{50} value of 4.85 ppm of the neem leaves extract was calculated for female adult of *M. hirsutus* after 72 hours of exposer and was further tested on the fresh eggs and nymphs of *M. hirsutus*. Contact exposing of the eggs and nymphs to neem leaves extract significantly reduced the % hatch rate of *M. hirsutus* eggs (45.23%) and caused significantly high mortality of the nymph (62.22%) after 72 hours as compared with the control. The sub-lethal effect of the neem leaves extracts on the female adult of *M. hirsutus* showed that the insects treated with 5% neem leaves extract concentration had significantly lower values of finite rate of increase *(λ)* (1.09±0.004 day^{-1}), intrinsic rate of increase (*r)* (0.08±0.004 day^{-1}) and net reproductive rate (R_o) (32.56±4.75 eggs/female) as compared with the population treated with lower neem leaves concentrations. Similarly, the age-stage specific life expectancy (e_{xj}) and age specific reproductive value (v_{xj}) of *M. hirsutus* were recorded lower when treated with 5% neem leaves extract as compared to other treatments. This study revealed that neem leaves extracts are highly effective in reducing *M. hirsutus* infestation and can be used in mealybug IPM programs.

Key Words: *Neem, Maconellicoccus hirsutus, Age-stage two sex Life table, Hibiscus, Hemiptera*

ID: 603

Effects of milking methods on test-day milk yield and milk quality traits in early lactating multiparous buffalo cows and the relationships among these parameters

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Abstract

Buffaloes are not fully adapted to machine milking because they are generally milked manually. Therefore, a comprehensive examination of the relationships between milking practices and productivity is critical to obtain high quality milk products. The aims of the present study were i) to investigate the effects of different milking methods on test-day milk yield (TDMY) and milk quality traits [dry matter (DM), fat, solids-not-fat (SNF), protein, fat-to-protein ratio (FPR), lactose, density, freezing point (FP), somatic cell count (SCC), pH and electrical conductivity (EC) in multiparous Anatolian buffalo cows and ii) to investigate the relationships among these milk quality traits. The study material consisted of 120 milk samples collected from 60 buffalo cows machine and hand milked in five barns at the same location on a family farm. The collected milk samples were analysed for their milk components (DM, fat, SNF, protein lactose, density and FP), SCC, pH value, and EC value using the following devices: i) a milk analyser, ii) a portable somatic cell counter, iii) a pH meter, and iv) an EC-meter equipped with a conductometric sensor. The statistical analyses were conducted using *t-test* and Pearson Correlation procedures. The quantitative (DM, fat, protein, density, SCC, EC, and pH)-qualitative (TDMY) milk parameters of hand-milked cows was found to be higher than that of machine-milked cows. Furthermore, a positive correlation was found between SCC and pH and EC values. It was determined that milk DM, SNF and lactose percentages decreased as TDMY value increased. The SCC and EC displayed a negative correlation with the milk fat percentages, and a positive correlation with milk mineral percentages. Although manual milking improves quantitative-qualitative milk parameters in buffalo cows, it may pose more risks to their udder health and milk hygiene. Therefore, the advantages and disadvantages of current milking practices should be carefully considered.

Key Words: *Buffalo cows, hand milking, machine milking, quantitative-qualitative milk parameters*

Introduction

It is evident that buffalo milk, which has high nutritional content, has recently attracted the consumers' interest because it can be transformed into high value-added products (Akdağ et al., 2024). Therefore, it is important to improve the quality and quantity traits of milk produced from buffalo cows (*Bubalus bubalis)*. The quantitative-qualitative milk parameters of buffalo cows (Okuyucu et al., 2024; Akdağ et al.,2024) can be influenced by i) resource-based factors (e.g. space allocation, barn facilities, soil and climatic factors), ii) management-based factors (e.g. handling strategies, breeding strategies, milking practices and health plan) and iii) animal-based factors (e.g. body condition, udder hygiene, lameness and milking temperament). Particularly, milking practices are important for buffalo cows because buffaloes are sensitive to non-routine practices and environmental stimuli (Napolitano et al., 2013). This process can cause considerable stress to buffalo cows (Erdem et al., 2022). As buffalo farming is predominantly extensive worldwide (Erdem et al., 2022), manual milking is a common practice. However, with increasing intensification, the use of mechanical milking on dairy farms has also increased. Therefore, the advantages and disadvantages of milking methods applied to buffalo cows should be carefully considered. Since manual milking is one of the most labour- and time-consuming practices, manual milkers may encounter health problems such as stiff shoulders, pain and weakness in the knee joints and spine (Khatri et al., 2021). In addition, contamination of the cow's teat in manual milking can result in an increase in microorganisms in milk. Although machine milking, which is another milking method, is beneficial in terms of milk hygiene and reducing labour use, the responsiveness of buffalo cows to machine milking may quantitative [dry matter (DM), fat, solids-not-fat (SNF), protein, fat-to-protein ratio (FPR), lactose, density, freezing point (FP), somatic cell count (SCC), pH and electrical conductivity (EC)]-qualitative [test-day milk yield (TDMY)] milk parameters (Erdem et al., 2022; Okuyucu et al., 2024; Akdağ et al.,2024). Therefore, milking cows under hygienic conditions with milking methods that provide optimum welfare conditions is the most critical management practice for quality milk production.

A large body of authors has reported that effective milk extraction plays an important role in milking techniques and procedures and can influence milk yield and its components (Argov-Argaman, 2019; Couvreur and Hurtaud, 2017; Palii et al.,2020). However, the literature on the effects of different milking methods on TDMY and milk components of buffalo cows is limited. The aims of this study were i) to investigate the effects of different milking methods on quantitative (DM, fat, SNF, protein, FPR, lactose, density, FP, SCC, pH and EC)-qualitative (TDMY) milk parameters and ii) to investigate the relationships among milk parameters.

Materials and Methods

This study was conducted in five barns at the same location on a family farm in Samsun, located in the Black Sea Region of Türkiye. The study material consisted of 120 milk samples collected from 60 multiparous buffalo cows machine and hand milked in barns (closed-tied-stall barns). The cows included in the study were cows of parity 2 (n= 10), 3 (n=10) and 4 (n=10). The data were collected during once per week visits to the farm between January 2025 and February 2025.All cows were not grazed on pasture and were fed ad libitum with a TMR in the barn. The TMR available consisted of wheat straw, maize silage and concentrate.

Routine practices on the farm were not changed throughout the study. The farm were visited and milk was collected twice during the study. Manual and machine milking practices were as shown in Table 1.

Table 1. Manual and mechanical milking processes

Milking methods	Milking processes		
	Milking processes	Pre-milking processes	Post-milking processes
Manual	Cows milked manually by two stockperson	Calves suckled their dams for approximately two minutes. Then, the cow's udders were washed with fresh water and dried with a clean cloth.	After the milking process no iodine teat dip was applied.
Machine	Each cow was milked individually with a portable milking machine (PLS-2/1; Sezer, Bursa, Türkiye).		

At the end of milking, the milk samples were weighed on an electronic scale and the TDMY values were determined. Approximately 50 ml of milk samples were then collected in plastic milk tubes. These samples were transported to the laboratory at 4°C to evaluate the content of milk components and physical traits. All analyses were performed when the milk was at 30°C to 32°C. The milk components (milk fat, protein, lactose, and mineral percentages), and physical traits [density (mg/mL), and the FP (°C)] of the milk samples were analyzed using an milk analyzer (Lactostar, Funke-Gerber, Germany). Furthermore, FPR were calculated as fat percentage/protein percentage. The milk EC (mS/cm) and pH were measured using an EC-meter equipped with a conductometric sensor (FiveEasy Plus, Mettler Toledo, Switzerland) and pH meter (Testo 205), respectively. The SCC value of the milk was determined using a portable cell counter (DeLaval, Tumba, Sweden).

The statistical analyses were conducted using the SPSS software program (version 21.0, SPSS Inc., Chicago, IL, USA). Prior to analysis, the normality and variance homogeneity of data from test-day records of quantitative (DM, fat, SNF, protein, lactose, mineral, density, FP, SCC, EC, and pH)-qualitative (milk yield) milk parameters were screened using the Kolmogorov-Smirnov and Levene's tests, respectively. The logarithmic transformation procedure was applied to the SCC data, which is one of the available milk quality traits, because the data did not show a normal distribution.

To determine the effects of milking practices on quantitative-qualitative milk parameters, *t-test* procedure was applied. To this end, the cows were allocated to ensure that an equal number of cows were represented in each group [machine (n=30) and manual (n=30) milking]. Correlation coefficients among these traits were calculated by applying Pearson correlation procedure.

Results and Discussion

In the present study, the mean values of quantitative-qualitative milk parameters of Anatolian buffalo cows in early lactation were as shown in Table 2. In previous studies on buffaloes, the mean TDMY (5.37 kg, Tripaldi et al., 2010; 5.7 kg, Şekerden, 2011; 3.96-4.53 kg, Sarıözkan et al., 2021) value was lower than the results obtained in the current study. However, the current results were higher than those (2.95 kg) reported by Özcan and Erdem, (2022). Furthermore, the milk DM percentage was higher than the findings reported in several studies (16.207-17.230%, Sahin et al., 2014; 14.18-15.67%, Sarıözkan et al., 2021; 17.29% for Nili-Ravi, 18.23% for Murrah, Abdel-Hamid et al., 2023), but lower than in other reported studies (20.18% for Mediterranean, Abdel-Hamid et al., 2023). The findings of this study demonstrated a congruence with the outcomes documented in several preceding studies, particularly with regard to the percentage of fat in milk (Özcan and Erdem, 2022; Yuan et al., 2022). Similarly, the milk protein percentage was also consistent with those reported in previous studies (4,515-4,955% for Anatolian Buffalo, Sahin et al., 2014; 4.38 % for Nili-Ravi, Abdel-Hamid et al., 2023). The percentage of milk lactose was higher than reported reported by Tripaldi et al. (2010). However, the percentage of lactose was lower than that reported in other studies (Özcan and Erdem, 2022; Yuan et al., 2022; Abdel-Hamid et al., 2023). Also, the milk mineral percentage was not in agreement with those reported by Özcan and Erdem, (2022).

The density value, which is one of the physical traits of milk, was consistent with those reported in previous studies (Sarıözkan et al., 2021; Özcan and Erdem, 2022). However, the milk FP value was not in agreement with those reported in previous studies (Özcan and Erdem, 2022; Okuyucu et al., 2024; Akdağ et al., 2024). The SCC value was lower than those reported in previous studies (Sarıözkan et al., 2021; Viana et al., 2024) but higher than those reported in others studies (Özcan and Erdem, 2022; Yuan et al., 2022). The milk pH value was consistent with those reported in previous studies (Şekerden and Avşar, 2008; Tripaldi et al., 2010). Similarly, the milk EC values were also in accordance with those reported in previous studies on Anatolian buffaloes (Okuyucu et al., 2024; Akdağ et al., 2024).

Table 2. Means test-day milk yield and milk quality traits of Anatolian buffalo cows

Variables	Number of records	Mminumum	Maximum	Mean	SE
Milk yield trait (kg)					
TDMY	120	2.00	4.78	3.38	0.066
Milk components (%)					
DM	120	14.99	23.46	18.62	0.241
Fat	120	6.10	12.35	8.48	0.169
SNF	120	7.13	13.39	10.14	0.160
Protein	120	3.00	6.09	4.40	0.093
FPR	120	1.19	4.00	1.98	0.060
Lactose	120	3.36	6.61	4.94	0.740
Mineral	120	0.45	0.98	0.65	0.013
Milk physical traits					
Density (mg/ml)	120	1.00	1.06	1.03	0.001
FP (˚C)	120	-0.42	-0.87	-0.60	0.014
SCC (x10^3 cells/ml)	120	10	347	76.4	7.333
logSCC	120	4.00	5.54	4.78	0.042
pH	120	6.23	7.00	6.59	0.027
EC (mS/cm)	120	3.00	5.30	3.50	0.070

TDMY: Test-day milk yield; DM: Dry matter; SNF: Solids-not-fat; FPR: Fat-to-protein ratio; SCC: Somatic cell count; FP: Freezing point; EC: Electrical conductivity

The TDMY obtained from machine milked cows was lower than those milked manually (p=0.018; Table 3). Similarly, the DM (p=0.028), fat (p=0.043) and protein (p=0.047) precentages and density (p=0.029) in the milk of machine milked cows was lower than that of hand milked cows. Although the design of this study was not suitable to prove the following hypotheses, the higher TDMY value, DM, fat and protein content in hand milked cows compared to machine milked cows may be related to i) negative effects of machine milking on oxytocin release mechanism of cows, ii) high reactivity (increase in behavioural responses) to machine milking and iii) machine milking equipment not being suitable for buffalo udder physiology (Okuyucu et al., 2024; Ahmet et al., 2024). It was a remarkable finding that milk SCC (p=0.049), pH (p=0.048) and EC (p=0.038) values, which are considered important indicators of udder health and milk quality, were higher in hand milked cows compared to machine milked cows. In a previous study on dairy cows, it was reported that the number of microorganisms (microorganisms x 1000/ml) in the milk of cows milked by hand was higher than that of cows milked by machine (Filipovic and Kokaj, 2009). In the same study, it was reported that the several milk components (fat and protein percentages) and SCC values of hand-milked cows were comparatively higher than those of machine-milked cows, although this difference was not statistically significant. Simlarly, milking methods (manual and machine milking) did not statistically affect milk components and SCC values (Sarıözkan et al., 2021; Li et al., 2024). The results obtained suggest that milk yield and the content of some milk components are positively influenced, whereas udder health (high SCC, pH and EC values) and milk hygiene may be negatively influenced.

Table 3. Means test-day milk yield and milk quality characteristics of cows according to milking practices

Variables	Milking methods		SEM	p-value
	Machine	Manual		
Milk yield trait (kg)				
TDMY	3.23	3.53	0.066	0.018
Milk components (%)				
DM	18.09	19.14	0.241	0.028
Fat	8.14	8.82	0.169	0.043
SNF	9.96	10.32	0.160	0.254
Protein	4.22	4.57	0.093	0.047
FPR	2.0	1.96	0.060	0.745
Lactose	4.91	4.98	0.740	0.629
Mineral	0.64	0.66	0.013	0.718
Milk physical traits				
Density (mg/ml)	1.02	1.03	0.001	0.029
FP (˚C)	-0.60	-0.61	0.014	0.838
SCC (x10^3 cells/ml)	61.5	91.2	7.333	0.049
pH	6.53	6.64	0.027	0.048
EC (mS/cm)	3.4	3.7	0.070	0.038

TDMY: Test-day milk yield; DM: Dry matter; SNF: Solids-not-fat; FPR: Fat-to-protein ratio; SCC: Somatic cell count; FP: Freezing point; EC: Electrical conductivity

The TDMY value of buffalo cows displayed a negative correlation with the milk DM (p=0.041), SNF (p=0.008), and protein percentages (p=0.005; Table 4).

Table 4. Correlations between the qualitative milk trait (TMDY) and quantitative milk traits examined

	DM	Fat	SNF	Protein	FPR	Lactose	Mineral	Density	FP
TDMY	-0.313 (p=0.041)	-0.040 (p=0.760)	-0.339 (p=0.008)	-0.201 (p=0.123)	0.093 (p=0.481)	-0.359 (p=0.005)	0.026 (p=0.843)	0.189 (p=0.148)	-0.144 (p=0.274)

TDMY: Test-day milk yield; DM: Dry matter; SNF: Solids-not-fat; FPR: Fat-to-protein ratio; SCC: Somatic cell count; FP: Freezing point; EC: Electrical conductivity

The SCC displayed a negative correlation with the milk fat percentages (p=0.030), and a positive correlation with milk mineral percentages (p=0.041; Table 5). Similarly, the EC values correlated positively with the mineral percentages (p=0.026) and negatively with the fat percentages (p= 0.003), FPR (p=0.024), and density values (p= 0.020). However, no statistically significant relationship was found between quantitative-qualitative milk parameters and pH (Table 5). High SCC in milk causes changes in milk enzymes. This may result in the breakdown of milk fat globules. The aforementioned statements elucidate the mechanism responsible for the observed decline in milk fat percentages concomitant with elevated SCC (Aytekin and Boztekin, 2014). Also, the SCC increases due to damage in the mammary tissue, resulting in increased Na+ and Cl concentrations (Aytekin and Boztekin, 2014). Thus, a high mineral content can lead to a significant increase in the EC value of milk.

Table 5. Correlations between milk components and SCC, pH and EC parameters

	SCC	pH	EC
TDMY	-0.068 (p=0.606)	-0.116 (p=0.375)	-0.030 (p=0.818)
DM	0.159 (p=0.225)	0.148 (p=0.258)	0.210 (p=0.107)
Fat	-0.280 (p=0.030)	-0.238 (p=0.067)	-0.383 (p=0.003)
SNF	-0.057 (p=0.668)	-0.028 (p=0.831)	-0.088 (p=0.506)
Protein	0.054 (p=0.684)	0.009 (p=0.944)	-0.048 (p=0.715)
FPR	-0.127 (p=0.335)	-0.119 (p=0.363)	-0.292 (p=0.024)
Lactose	-0.046 (p=0.729)	0.023 (p=0.864)	-0.012 (p=0.927)
Mineral	0.265 p=0.041	0.177 (p=0.177)	0.287 (p=0.026)
Density	-0.206 (p=0.115)	-0.063 (p=0.634)	-0.299 (p=0.020)
FP	0.018 (p=0.892)	-0.092 (p=0.484)	0.071 (p=0.591)

TDMY: Test-day milk yield; DM: Dry matter; SNF: Solids-not-fat; FPR: Fat-to-protein ratio; SCC: Somatic cell count; FP: Freezing point; EC: Electrical conductivity

A positive correlation was found between SCC and pH values (p<0.001). Furthermore, the highest correlation coefficient was calculated between SCC and EC (r = 0.710; p<0.001; Table 6). Similarly, in a study conducted on Mediterranean buffalo cows (Tripaldi et al., 2003), it was reported that milk pH increased as SCC increased. In a another study on Murrah cross buffaloes, a positive correlation was found between SCC and EC values (Dhakal et al., 2008). The findings were consistent with those reported in previous studies (Tripaldi et al., 2003; Dhakal et al., 2008). The present results indicate that pH and EC parameters can be reliably used to indirectly assess udder health and SCC.

Table 6. Correlations between SSC, ph and EC values

	pH	EC
SCC	0.511 (p<0.001)	0.710 (p<0.001)
pH		0.382 (p=0.003)

SCC: Somatic cell count; FP:Freezing point; EC: Electrical conductivity

In the present study, hand milked buffalo cows had higher milk yield and some milk components but higher SCC, which are considered important indicators of milk hygiene and udder health, compared to machine milked buffalo cows. Although available evidence suggests that manual milking improves milk yield and milk composition, it also poses a risk to milk hygiene and udder health. Also, manual milking, a common practice on buffalo dairy farms, is one of the most labour- and time consuming practices. In this regard, manual milkers may encounter health problems such stiff shoulder, pain in knee joints and backbone and weakness (Khatri et al.,2021). Therefore, the advantages and disadvantages of differences in the milking methods of buffalo cows should be carefully examined. Furthermore, the effects of these methods on both animal welfare and the quality of the human-animal interaction should be investigated in detail.

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ID: 604

Multivariate Analysis Of The Effect Of Different Pre-Treatment Methods Before Drying On Some Quality Properties Of Potato

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Abstract

In this study, it was aimed to investigate the physicochemical properties of potato powder obtained from different pre-gelatinization processes applied to yellow-fleshed potato. Steam , microwave , ultrasonication, and thermosonication blanching were applied as pre-gelatination processes. A control sample dried at 55°C, without any pretreatment, was taken as a reference to compare the effect of the treatments on physicochemical properties. Total phenolic content, antioxidant activity, color, water activity, ash and moisture content were analyzed in potato powders dried at 55°C after preliminary gelatinization processes. It was observed that pre-treatments caused a decrease in bioactive substance content while improving color values. Moreover, each of the different pregelatinization treatments gave different results. Steam blanching was the closest to the control sample in terms of preservation of bioactive components and ash content. This is considered an important study in terms of adding new information to the literature with the results obtained using different pregelatinization techniques on potatoes.

Key Words: *Potato, pre-gelatinization, bioactive compound, color, drying*

ID: 605

Isolation of Cellulolytic Bacterium from the Digestive Tract of the *Leptinotarsa decemlineata* (Colorado Potato Beetle)

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Abstract

The objective of this study was to isolate and identify cellulose-degrading bacteria from the adult digestive tract of the *Leptinotarsa decemlineata* (Colorado potato beetle). Soluble carboxymethyl cellulose (CMC) degradation assays were used to identify five bacterial strains and assess their cellulolytic activity. The development of a clear zone on CMC plate media and the cellulolytic index were used to calculate cellulolytic activity. The highest cellulolytic index (2.2) was found in MOC6. This strain was identified and described using morphological, biochemical, and partial 16S rDNA sequencing. New cellulose-degrading bacteria from the *Leptinotarsa decemlineata*'s gut have been identified in this investigation. The isolate had relatively high cellulolytic activity was identified as *Bacillus pumilus* strain MOC6. The potential use of this strain in the breakdown of cellulose makes its identification significant.

Key Words: Cellulolytic bacterium, Digestive tract, *Leptinotarsa Decemlineata*

Introduction

The most diverse and prevalent group of animals on the planet are insects, whose ability to survive depends mostly on their exceptional environmental adaptations and food sources. In order to accomplish this, insects have developed highly specialized and complex digestive systems that can break down a wide range of meals, primarily lignocellulose, which is the dry substance found in plant cell walls (Dar et al., 2022). The guts of insects are home to a variety of bacteria that benefit their hosts physiologically and ecologically (Ozdal et al., 2016; Jang and Kikuchi, 2020). Insect digestive systems have been known as the smallest natural bioreactors in the world because of their exceptional lignocellulose digestion (Breznak and Brune, 1994).

Among this diverse group of insects, one species with significant agricultural importance is Leptinotarsa decemlineata (Colorado potato beetle). Belonging to the order Coleoptera and the family Chrysomelidae, this species is a pest primarily feeding on plants of the Solanaceae family, causing substantial yield losses in potato fields worldwide (Muratoğlu et al. 2011). The adult individuals measure 10–12 mm in length, with a yellow-reddish coloration and a strongly convex dorsal surface. The elytra bear a total of ten longitudinal black stripes, five on each side. The mature larvae have a hunched posture, with a dark brown head and a bright orange body (Kekillioğlu and Yılmaz, 2018). *L. decemlineata* overwinters in the soil as an adult. In the spring, it leaves its overwintering sites in search of host plants, during which process it can disperse over large areas (Muratoğlu et al., 2011).

In terms of feeding habits, *L. decemlineata* primarily consumes the leaves of the plant, and then feeds on the stems and tubers. Both larvae and adults typically feed by starting from the edges of the leaves and moving inward, or by creating holes on the leaf surface and continuing to feed (Bouchard et al., 2003). The most destructive period is the late larval stage, which accounts for approximately 90% of total leaf consumption. Furthermore, *L. decemlineata* not only causes physical damage but also serves as a vector for various pathogens, including brown rot, potato ring rot, and spindle tuber viroid**.** The feeding habits and digestive processes of *L. decemlineata* result in a significant specialization of its gut microbiota. The gut of *L. decemlineata* supports a complex microbiota capable of degrading lignocellulose and other plant-derived components (Efimenko et al., 2022).

The aim of this study is to isolate cellulolytic microorganisms from the *L. decemlineata* gut. Numerous insect guts have been found to harbor significant populations of bacteria with cellulolytic activity. (Uddin et al., 2021; Han et al., 2024). Therefore, insects are considered attractive biological sources for discovering new cellulolytic enzymes with extraordinary catalytic potential.

Materials and Methods

Collection of *Leptinotarsa decemlineata* specimens

Leptinotarsa decemlineata collected from potato fields in Erzurum, Pasinler were used in the study. The collected adult specimens were placed in glass jars. These jars were covered with a fine-mesh cloth and transported to the laboratory environment where the experiments were carried out. The beetles were fed on potato plant leaves for a week.

Isolation of bacteria

The beetles were surface sterilized in 70% ethanol, rinsed with sterile distilled water and air dried for 5 minutes at room temperature (25ºC). The beetles were then dissected with a sterile scalpel and the entire gut was removed and suspended in 20 ml of 0.85% NaCl. 0.2 ml of the gut suspension was inoculated into Nutrient Agar (NA, Merck). After 24 hours, colonies that developed on the medium were isolated separately.

Morphological and molecular identification of the bacterial isolates

A colony of each isolate was then moved onto sterile glass slides after the isolates had been subcultured on nutrient agar plates for twenty-four hours. The KOH test (Powers, 1995) and Gram stain (Coico, 2006) were used. To find the gram response, the KOH test employs 3% potassium hydroxide. The cultural, morphological and biochemical properties of the bacterial species (Gram, cell shape, catalase, oxidase) were determined (Harley and Prescott, 2002; Ozdal et al., 2016). The 16S rDNA gene was utilized for molecular identification.

Screening for cellulose-degrading capacity

The isolated bacteria were inoculated individually onto Nutrient Agar (NA, Merck) medium containing 1% CMC. CMC degradation was tested by staining the plates with 1 g/L congo red dye (Sigma, USA) for 15 min and then washing with 1M NaCl. After staining with congo red dye, clear zones around bacterial colonies on CMC plates indicated cellulolytic activity. Cellulase activity index (CAI) was then calculated according to the following equation CAI=[(Diameter clear zone – Diameter bacterial colony)/Diameter bacterial colony] (Handique et al., 2017; Nelson et al., 2021).

Results and Discussion

A total of twenty bacterial strains were isolated from adult digestive tract of the *Leptinotarsa decemlineata*. Purified isolates were screened on CMC plates for cellulase activity. Based on the widths of the clear hydrolysis zones surrounding the colonies on CMC plates, five possible cellulotic isolates were chosen for the quantitative cellulase activity assay (Figure 1).

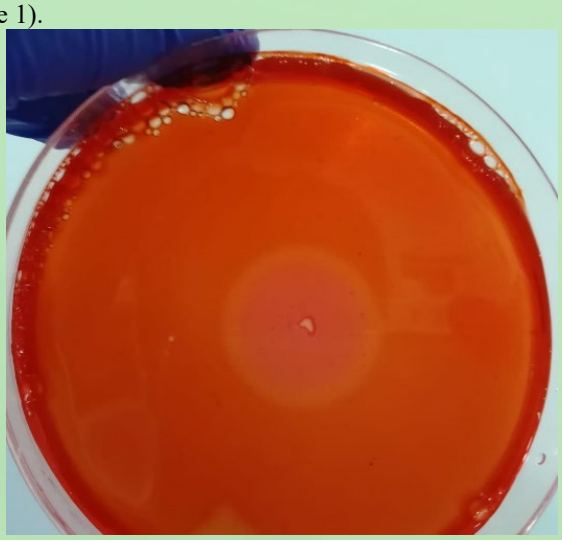


Figure 1. Cellulolytic hydrolysis zones around the streaks of isolate grown on CMC plate for 2 days at 30 °C.

In this study, three Gram-positive and two Gram-negative bacterial species that were determined to produce cellulase were isolated. Additionally, it was shown that every isolated bacterium exhibited catalase and protease activity (Table 1). A range of 0.8 to 2.2 for the cellulolytic index indicated significant cellulase production. MOC6 had the highest cellulolytic index (2.2), whereas MOC3 had the lowest (0.8) (Table 1). The sequence data based on 16 S rDNA region analysis, were compared with sequences in the NCBI database. The MOC6 isolate was identified as *Bacillus pumilus*.

Bacillus group is commonly found in many insect digestive systems due to its cellulolytic properties. The study by MsangoSoko et al. (2020) supports these results; Bacillaceae was reported as the dominant group of cellulolytic gut bacterial symbionts in Coleopteran insects. *B. licheniformis* cellulolytic bacteria have been reported isolated from the gut of white worm species (Van Dyk et al., 2009). Similar to the B. pumilus bacteria we isolated in this study, there are many studies showing that this species produces cellulase (Shankar et al., 2021; Dar et al., 2022; Yilmaz and Gurkok, 2025).

Table 1. Identification of cellulase producing isolates on the basis of morphological / biochemical tests and cellulolytic activities.

Tests	MOC3	MOC4	MOC5	MOC6	MOC7
Gram strain	+	+	-	+	-
Catalase	+	+	+	+	+
Oxidase	+	+	-	+	-
Urease	-	-	+	-	+
Protease	+	+	+	+	+
Shape	Rod	Rod	Rod	Rod	Rod
CAI	0.8	1.3	2.0	2.2	1.6

The findings of this article were that bacteria with cellulolytic activity were isolated from the digestive system of the *Leptinotarsa decemlineata* and *B. pumilus* was determined as the most effective species. In conclusion, complex cellulose-rich organic wastes may be broken down by cellulolytic bacteria that were isolated from *L. decemlineata* guts. Therefore, more research is required to assess how well these cellulolytic bacterial strains break down organic waste and agricultural byproducts. In order to prepare strong strains of bacterial consortium that degrade organic matter and use them for the generation of biofuel at the industrial level, more research is necessary to identify and characterize cellulolytic bacteria from the gut of cellulolytic-feeding *L. decemlineata*.

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Cloud Point Extraction for the Recovery of Bioactive Compounds from Peanut Shells

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Abstract

Peanuts (*Arachis hypogaea* L.) belong to the legume family and originated in South America. Over time, they have spread to various parts of the world, especially China, India, the United States, and Türkiye. According to 2019 data, about 48 million tons of peanuts are produced worldwide, with Turkey producing 169 thousand tons of this amount. Anatomically, peanuts consist of three parts: the shell, membrane, and kernel. These components differ in the bioactive compounds they contain. During processing, these parts are separated at various stages in the factory. However, these by-products are often not sufficiently valorized, leading to underutilization of their potential. In recent years, waste valorization has gained significant attention in the peanut industry. Peanut shells highlight their potential as a valuable and sustainable resource. Moreover, extracting bioactive compounds from these by-products using innovative methods has become a key focus of recent research. The aim of this study was to recover the bioactive potential of peanut shell waste using a cloud point extraction technique, employing lecithin as a surfactant. Different parameters were tested through single-factor analysis, one at a time. An increase in the bioactive potential of peanut shells was recorded when the surfactant concentration was 10% w/v, the phase separation temperature was 90 °C for 40 minutes, the salt concentration was 10% w/v, and the pH was 2. The cloud point extraction method is regarded as an advantageous technique for recovering the total phenolic content potential of peanut shell waste.

Keywords: *Peanut shell, bioactive compounds, cloud point extraction*

Yer Fıstığı Kabuklarından Bulutlanma Noktası Ekstraksiyon ile Biyoaktif Bileşiklerin Geri Kazanımı

Özet

Yer fıstığı (*Arachis hypogaea* L.) baklagiller familyasına aittir ve Güney Amerika kökenlidir. Zamanla dünyanın farklı bölgelerine yayılarak, özellikle Çin, Hindistan, Amerika Birleşik Devletleri ve Türkiye gibi birçok ülkede yetiştirilmiştir. 2019 yılı verilerine göre dünyada yaklaşık 48 milyon ton yer fıstığı üretilirken, Türkiye'de bu miktar 169 bin ton olarak kaydedilmiştir. Yer fıstığı anatomik olarak üç bölümden oluşur: kabuk, zar ve tohum. Bu kısımlar, içerdiği biyoaktif bileşenler açısından farklılık göstermekle birlikte yer fıstığı işlenirken, fabrikada çeşitli aşamalarda ayrılmaktadırlar. Ancak, bu yan ürünler genellikle yeterince değerlendirilmemekte ve potansiyelleri yeterince bilinmemektedir. Son yıllarda, atık değerlendirme yer fıstığı endüstrisinde de önemli derecede dikkat çekmiştir. Yer fıstığı kabuklarının, değerli ve sürdürülebilir bir kaynak olarak potansiyeli vurgulanmaktadır. Ayrıca, bu yan ürünlerden yenilikçi yöntemler kullanarak biyoaktif bileşenlerin çıkarılması son araştırmalarda önemli bir odak haline gelmiştir. Bu çalışmanın amacı, yerfıstığı kabuğu atığının biyoaktif potansiyelini bulutlanma noktası ekstraksiyon tekniği ile geri kazanmaktır. Bu süreçte, lesitin yüzey aktif madde olarak kullanılmıştır. Farklı parametreler için, tek faktörlü analiz yöntemi kullanılarak denemeler gerçekleştirilmiştir. Yer fıstığı kabuklarının biyoaktivite potansiyelindeki artış, yüzey aktif madde konsantrasyonunun %10 w/v, faz ayrışma sıcaklığının 90 °C'de 40 dakika, tuz konsantrasyonunun %10 w/v ve pH'ın 2 olduğu durumlarda kaydedilmiştir. Bulutlanma noktası ekstraksiyon yönteminin, yer fıstığı kabuğu atıklarının toplam fenolik ve flavonoid potansiyelinin geri kazanımı için son derece avantajlı bir yöntem olduğu düşünülmektedir.

Anahtar Kelimeler: *Yer fıstığı kabuğu, biyoaktif bileşikler, bulutlanma noktası ekstraksiyonu*

Giriş

Yer fıstığı (*Arachis hypogaea* L.), dünya genelinde esas olarak tohumu ve yağı için yetiştirilen, protein açısından zengin bir baklagil bitkisidir (Bertioli ve vd., 2011). Yer fıstığı, çok yönlü kullanım alanları nedeniyle küresel ölçekte önemli bir endüstriyel üründür (Sorita vd., 2020). Besin açısından zengin içeriği, sağlığa faydalı özellikleri ve kendine özgü aroması sayesinde dünya genelinde yaygın olarak tüketilmektedir.

2019 yılında dünya genelinde 30 milyon hektar alanda 49 milyon ton kabuklu yer fıstığı üretilmiş, üretimin büyük kısmı Çin, Hindistan ve Nijerya'dan sağlanmıştır. Son 60 yılda dünyada ve Türkiye'de yer fıstığı ekim alanları artarken, tarım teknolojilerindeki ilerlemelerle birim alandaki verimlilik de yükselmiştir. Türkiye'de 2020 yılında 215 bin hektar alanda 55 bin ton yer fıstığı üretilmiş olup, üretimin büyük bölümü Çukurova bölgesinde, özellikle Adana ve Osmaniye illerinde gerçekleşmektedir. Türkiye, yer fıstığı üretiminde genellikle kendi ihtiyacını karşılamakta olup, zaman zaman küçük oranlarda ithalat gerçekleştirmektedir (FAOSTAT, 2020).
Türkiye'de Virginia tipi yer fıstıkları, nispeten düşük yağ içeriği ve iri taneli yapıları nedeniyle üretim ve ithalatta tercih edilmekte; genellikle atıştırmalık gıda olarak tüketilmektedir.(Şahin, 2014). Osmaniye'de yetiştirilen yer fıstığı, 2002 yılında Türk Patent ve Marka Kurumu'ndan 54 numaralı tescil belgesi ile coğrafi işaret almıştır. Türkiye'deki yer fıstığı verimi dünya ortalamasının iki katından fazladır (Çiftçi, 2022).
Yer fıstığı kabuk, zar ve tohum (tane) olmak üzere üç ana bölümden oluşmaktadır (Win vd., 2011). Biyoaktif bileşenlerin bileşimi ve miktarı yer fıstığının farklı kısımlarında değişiklik göstermektedir (Zhao vd., 2012). Örneğin çiğ yer fıstığı tanesi; *p*- hidroksibenzoik asit, klorojenik asit, *p*-kumarik asit, kuersetin ve kaempferol polifenolleri içermektedir. Yer fıstığında fenolik bileşikler açısından en zengin bölüm zardır; bu kısım özellikle epikateşin ve kateşin gibi bileşenleri içermektedir. Luteolin ise yer fıstığı kabuğunda en fazla bulunan bileşik olarak rapor edilmiştir (Win vd., 2011, Liu vd., 2022).
Biyoaktif bileşiklerin ekstraksiyonu için yeni teknolojilerin kullanılması ile ekstraksiyon veriminin ve elde edilen bileşiklerin fonksiyonel ve besinsel özelliklerinin iyileştirilebileceği bilinmektedir (Imran vd., 2022). Yer fıstığı kabuğundan fenoliklerinin ekstraksiyonunda çoğunlukla Sokshalet, katı-sıvı ekstraksiyonu veya sıvı-sıvı ekstraksiyonu gibi geleneksel yöntemler çözücü olarak ise metanol, etanol, aseton, dietil eter ve etil asetat kullanılmıştır. Bu yöntemler yüksek verimli ve biyoaktif özellikleri korunmuş ekstraktlar elde edilmesine imkan sağlasa da uzun ekstraksiyon süreleri, fazla çözücü kullanılması ve çoğu toksik olan çözücülerin ekstraktta kalıntı bırakması gibi nedenlerle yerini son yıllarda yenilikçi ekstraksiyon tekniklerine bırakmaktadır. Bulutlanma noktası ekstraksiyon (BNE), biyoaktif bileşiklerin karmaşık matrikslerden etkili bir şekilde ayrıştırılması ve konsantre edilmesine olanak tanıyan yenilikçi bir ekstraksiyon tekniğidir. Ayrıca, geleneksel çözücü bazlı yöntemlere kıyasla daha çevre dostu ve sürdürülebilir bir süreç sunmasıyla öne çıkmaktadır.(Motikar vd., 2021). Bu yöntem, hedef moleküllerin yüzey aktif maddeler aracılığıyla karmaşık materyallerden seçici olarak ayrılması ve izole edilmesine dayanmaktadır (More vd., 2022). BNE işleminde, hedef molekül ve yüzey aktif madde içeren sulu çözelti, bulutlanma noktası sıcaklığının üzerine ısıtıldığında, yüzey aktif madde hedef molekülleri kapsülleyerek misel yapıları oluşturur. Bunun sonucunda, yoğunluk farkları nedeniyle sulu faz ve miseller iki farklı faza ayrılmaktadır (More vd., 2019). BNE, düşük çözücü tüketimi, ekonomik oluşu, çevre dostu yapısı ve enstrümantasyon açısından sağladığı kolaylıklar gibi çeşitli avantajlara sahip bir ayırma yöntemidir (Katsoyannos vd., 2006). Bu yöntemin etkinliği; kullanılan yüzey aktif maddenin türü ve miktarı, inkübasyon sıcaklığı (Melnyk vd., 2015), ortamın pH değeri (Sun vd., 2006), inkübasyon süresi (Gökkaya, 2014) ile tuz konsantrasyonu (Ulusoy vd., 2013) gibi çeşitli faktörlerden etkilenmektedir.
Son yıllarda, tarımsal atıklardan biyoaktif bileşenlerin yenilikçi ekstraksiyon teknikleriyle geri kazanılması, bilimsel çalışmaların odak noktalarından biri hâline gelmiştir. Bu bağlamda, bu çalışmanın amacı; yer fıstığı kabuğu atığındaki biyoaktif potansiyelin, çevre dostu ve seçici bir yöntem olan BNE kullanılarak geri kazanılmasını sağlamaktır.

Materyal ve Yöntem

Bu çalışmada kullanılan yer fıstığı kabukları (Virginia market tipi), Osmaniye'de faaliyet gösteren ve bölgedeki önemli yer fıstığı işleme tesislerinden 2024 yılında temin edilmiştir. Kabuğun elde edildiği işlem aşaması, ticari üretim sürecinde uygulanan ıslak kırım yöntemidir. Bu yöntemde, yer fıstıkları mekanik kırma işleminden önce su ile nemlendirilerek kabukların yumuşaması sağlanmakta ve böylece çekirdeğin kabuktan daha kolay ayrılması hedeflenmektedir. Çalışmada kullanılan yer fıstığı kabukları, ıslak kırım sonrası elde edilen kabuk atığıdır. Atık, fabrikada üretim hattından çıktıktan hemen sonra toplanmış ve olası mikrobiyal bozulmaların önlenmesi amacıyla açık havada 2 gün boyunca kurutularak stabilize edilmiş ve ondan sonra laboratuvara getirilmiştir. Fıstık kabukları 500'er gramlık porsiyonlar halinde vakumlanarak oda sıcaklığında depolanmıştır. Bu depolama yöntemi, numunelerin tazeliğini ve özelliklerini korumak amacıyla uygulanmıştır.

Bulutlanma Noktası Ekstraksiyon Yöntemi

Ekstraksiyon için (0.05, 0,1 ve 0,15 gram) öğütülmüş yer fıstığı kabuğu 50 mL distile su içeren bir Falcon tüpüne alınarak süspanse edilmiştir. Karışım, oda sıcaklığında ve karanlık ortamda 1 saat bekletilmiştir. Ardından katı-sıvı ayrımı için süspansiyon, 10000 rpm'de 10 dakika boyunca oda sıcaklığında santrifüj edilmiştir. Elde edilen süpernatant, kaba partiküllerin uzaklaştırılması amacıyla Büchner hunisi ve kaba gözenekli filtre kağıdı kullanılarak süzülmüştür. Berraklaştırılan sıvı faza, belirlenen konsantrasyonda yüzey aktif madde (%10) eklenmiş ve vorteks karıştırıcı ile homojen karışım elde edilmiştir. Çözeltinin pH değeri (2-4-6), pH metre ile ayarlanmıştır. Ardından belirli miktarda sodyum klorür (NaCl) (%8, %10, %15) eklenmiş ve tamamen çözünmesi sağlanmıştır. Karışım, (70-80-90°C) belirli bir sıcaklık değerlerine ayarlanan su banyosuna bırakılmıştır. Faz ayrımını

netleştirmek amacıyla karışım, 7500 rpm'de 10 dakika süreyle tekrar santrifüjlenmiştir. Santrifüjleme işlemi sonucunda, biri yüzey aktif maddece zengin, jelatinöz yapıda ve fenolik ile flavonoid bileşikler içerdiği düşünülen; diğeri ise sulu faz olmak üzere iki ayrı faz elde edilmiştir.

Toplam Fenolik Madde Analizi

Ekstraktların toplam fenolik bileşik miktarı Shahidi ve Ambigaipalan, (2015)'e göre yapılmıştır. Bir deney tüpü içerisine uygun oranda seyreltilen örneklerden 0.2 mL ve 1.5 mL 10 kat seyreltilmiş 2 N Folin-Ciocalteu reaktifi eklenmiştir. Tüp vortekste iyice karıştırılıp beş dakika bekledikten sonra üzerine 1.5 mL sodyum karbonat (%6, ağırlık/hacim (a/h)) eklenmiş ve tüpler yeniden vortekslenmiştir. Kör çözelti ise ekstrak yerine tüpe aynı miktarda saf su ilave edilerek, diğer işlemler aynı olacak şekilde hazırlanmıştır. 1,5 saat oda koşullarında ve karanlık bir ortamda bekletilen örnekler 765 nm'de spektrofotometrede köre karşı okunmuştur. Sonuçlar ise oluşturulan standart eğri kullanılarak gallik asit cinsinden ifade edilmiştir.

Toplam Flavonoid Madde Analizi

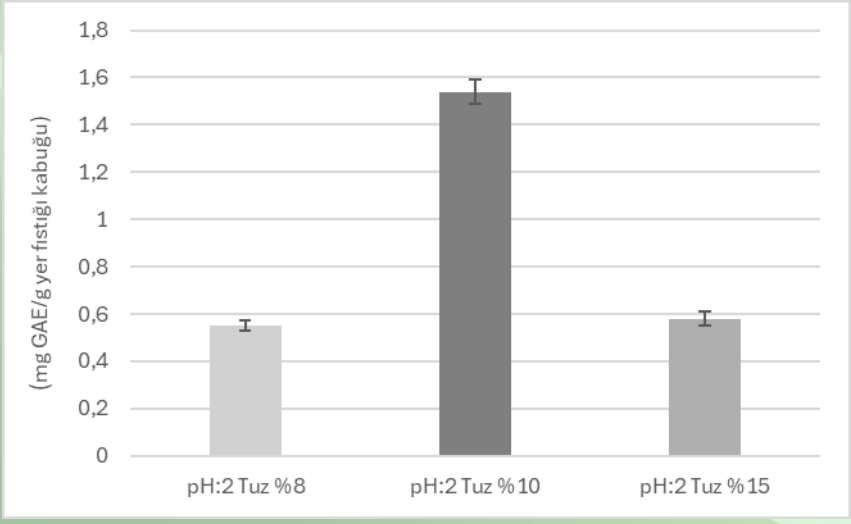
Ekstraktların toplam flavonoid bileşik miktarı Zhishen vd., (1999)'e göre yapılmıştır. Bir deney tüpü içerisine uygun oranda seyreltilen örneklerden 2 mL ve 150 µL sodyum nitrit (%5 a/v) eklenip, tüp vortekste iyice karıştırılıp beş dakika bekledikten sonra üzerine 150 µL alüminyum klorür (%6, a/v) eklenerek tüpler yeniden vortekslenmiştir. Üzerine 1 mL sodyum hidroksit eklenip vortekslendikten sonra 1,2 mL saf su eklenerek hazırlanmıştır. Kör çözelti ise ekstrakt yerine tüpe aynı miktarda saf su ilave edilerek, diğer işlemler aynı olacak şekilde hazırlanmıştır. 10 dakika oda koşullarında ve karanlık bir ortamda bekletilen örnekler, 510 nm'de spektrofotometrede köre karşı okunmuştur. Sonuçlar, oluşturulan standart eğri kullanılarak luteolin cinsinden ifade edilmiştir.

Bulgular ve Tartışma

Bulutlanma noktası ekstraksiyonu üzerine pH, tuz konsantrasyonu, sıcaklık ve örnek madde miktarının etkileri incelenmiş olup bu parametrelerin, biyoaktif bileşiklerin geri kazanım verimi üzerindeki etkilerini değerlendirmek amacıyla deneyler gerçekleştirilmiştir. Bu kapsamda, en yüksek verimle biyoaktif bileşiklerin elde edilmesini sağlayan koşullar belirlenmeye çalışılmıştır.

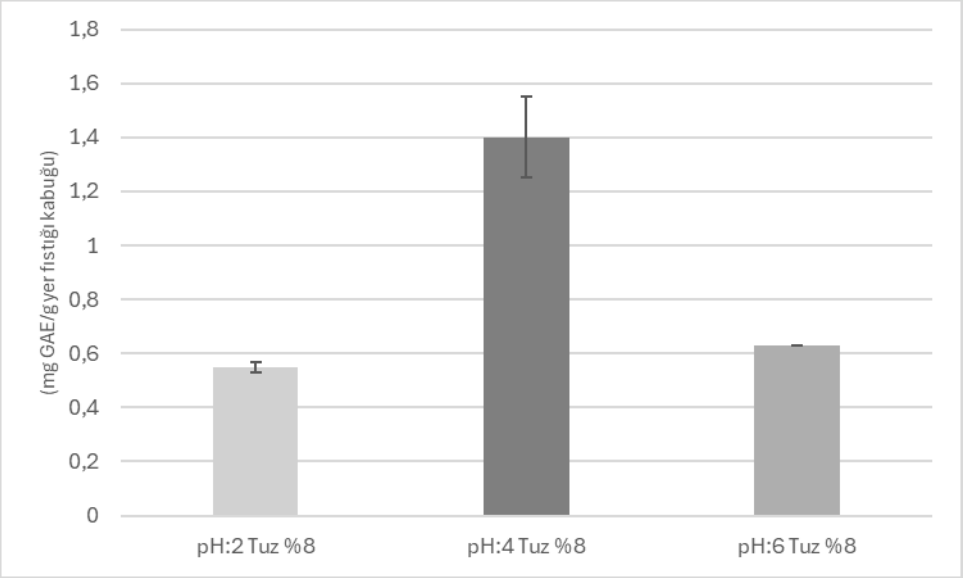
pH ve Tuz Etkisi

Şekil 1'de, farklı tuz konsantrasyonlarının (%8, %10 ve %15) toplam fenolik bileşik miktarı üzerine etkisi, pH 2 koşullarında sabit tutulmak suretiyle değerlendirilmiştir. Deneysel bulgular, en yüksek toplam fenolik bileşik kazanımının %10 tuz konsantrasyonunda gerçekleştiğini göstermiştir. Bununla birlikte, tuz konsantrasyonu %10'u geçtiğinde, toplam fenolik madde miktarında belirgin şekilde azalma olmuştur. Benzer şekilde Ji vd. (2021) yaptıkları çalışmada tuz konsantrasyonunun %5'ten %10'a yükseltilmesiyle BNE veriminin iyileştiğini, ancak tuz konsantrasyonun %10'u geçtikten sonra verimin anlamlı değişiklikler göstermediğini bildirmiştir. Bu artışın, NaCl gibi elektrolitlerin misel sistemindeki misel sayısını artırarak faz ayrımını kolaylaştırmasından kaynaklandığı bildirilmiştir (El-Abbasi vd., 2014; Ji vd., 2021). More ve Arya (2019) ise tuzun düşük konsantrasyonlarda (%4-6) salting-out etkisiyle verimi arttırırken, yüksek tuz konsantrasyonunun (>%8) kritik faz ayrım sıcaklığını düşürerek biyoaktif bozunmaya ve verim kaybına yol açtığını rapor etmiştir. Araştırmacılar optimum performans için %6-8 NaCl aralığını önermiştir.



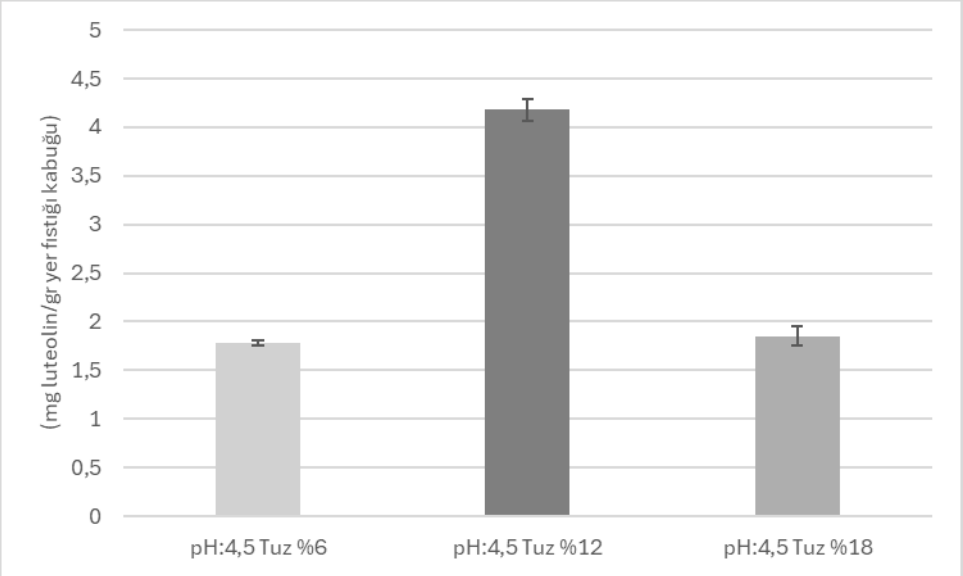
Şekil 1. Sabit pH'da tuz konsantrasyonunun toplam fenolik madde miktarına etkisi

Şekil 2'de, pH parametresinin (pH 2, 4 ve 6) toplam fenolik bileşik miktarı üzerindeki etkisi değerlendirilmiş; bu süreçte tuz konsantrasyonu %8'de sabit tutulmuştur. Yapılan analizler, sabit tuz konsantrasyonunda en yüksek toplam fenolik bileşik kazanımının pH 4 koşulunda gerçekleştiğini ortaya koymuştur. Benzer şekilde More ve Arya (2019) pH 4'te toplam fenolik madde için %95 verim sağladığını bildirmiştir. pH değeri, BNE yönteminde önemli bir rol oynar. Düşük pH (asidik koşullar), fenolik ve flavonoid bileşiklerin yüksüz formda kalmasını sağlayarak surfaktan miselleri tarafından daha kolay tutulmalarına yardımcı olur. Benzer şekilde More ve Arya (2019), pH 4 gibi asidik koşullarda hem toplam fenolik madde hem de toplam flavonoid için yüksek geri kazanım oranları elde etmiştir. pH'nın 6'ya çıkarılmasıyla toplam fenolik madde miktarında belirgin bir azalma gerçekleştirmiştir. Bu durum Kiai vd. (2018) ile El-Abbassi vd. (2014)'nin de bildirdiği gibi, çözeltinin pH'ının artmasının fenollerin yüzey aktif madde fazından ayrışmasını artırarak biyoaktif bileşik kaybına yol açması ile açıklanabilir. Sonuç olarak, pH kontrolü, hedef bileşiklerin kimyasal stabilitesi ve surfaktan-misellerle etkileşimi açısından kritiktir ve yer fıstığı kabuklarının BNE'nunda en yüksek verim ve en düşük kayıp için asidik pH aralığı daha etkili olmuştur.



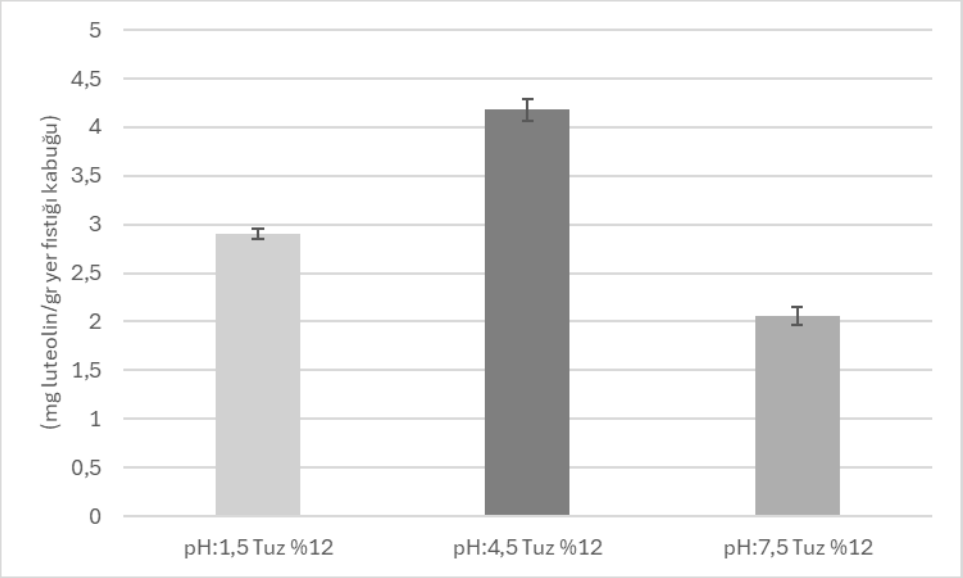
Şekil 2. Sabit tuz konsantrasyonunda pH'nın toplam fenolik madde miktarına etkisi

Şekil 3'de, farklı tuz konsantrasyonlarının (%6, %12 ve %18) toplam flavonoid bileşik miktarı üzerine etkisi, pH 4,5 koşullarında sabit tutulmak suretiyle değerlendirilmiştir. Deneysel bulgular, en yüksek toplam flavonoid bileşik kazanımının %12 tuz konsantrasyonunda gerçekleştiğini göstermiştir. Bununla birlikte, tuz konsantrasyonu %12'yi geçtiğinde, toplam flavonoid madde miktarında belirgin şekilde azalma olmuştur.



Şekil 3. Sabit pH'da tuz konsantrasyonunun toplam flavonoid madde miktarına etkisi

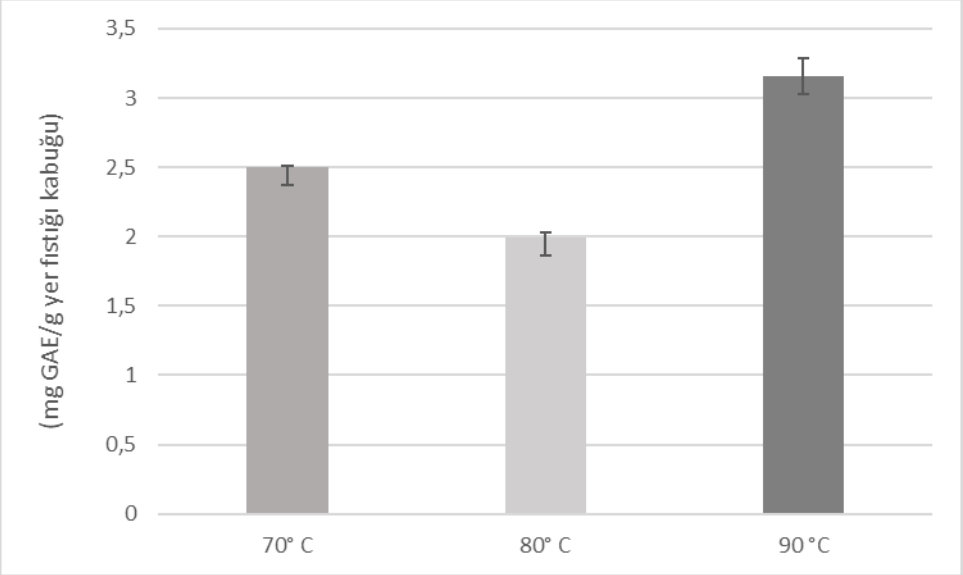
Şekil 4'de, pH parametresinin (pH 1,5 , 4,5 ve 7,5) toplam flavonoid bileşik miktarı üzerindeki etkisi değerlendirilmiş; bu süreçte tuz konsantrasyonu %12'de sabit tutulmuştur. Yapılan analizler, sabit tuz konsantrasyonunda en yüksek toplam flavonoid bileşik kazanımının pH 4,5 koşulunda gerçekleştiğini ortaya koymuştur. Benzer şekilde De Araújo Padilha ve arkadaşları camu-camu meyve atıklarından polifenol geri kazanımında bulutlanma noktası ekstraksiyonu yöntemini kullanmıştır. Çalışmada pH ve sodyum klorürün ekstraksiyon üzerindeki etkileri detaylı şekilde incelenerek, pH değeri 2–10 aralığında test edilmiş ve ekstraksiyon için en uygun pH aralığı araştırılmıştır. Ayrıca, %0–10 aralığında sodyum klorür konsantrasyonları değerlendirilmiş ve tuz ilavesinin toplam polifenol geri kazanımını anlamlı düzeyde azalttığı görülmüştür. Sonuç olarak, pH ayarlaması yapılmaksızın, %80 camu-camu ekstraktı, %7 Triton X-114 ve sodyum klorür içeren sistemle, 30 °C'de 3 saat süren ekstraksiyon sonucunda %95,71 oranında polifenol geri kazanımı elde edilmiştir.



Şekil 4. Sabit tuz konsantrasyonunda pH'nın toplam flavonoid madde miktarına etkisi

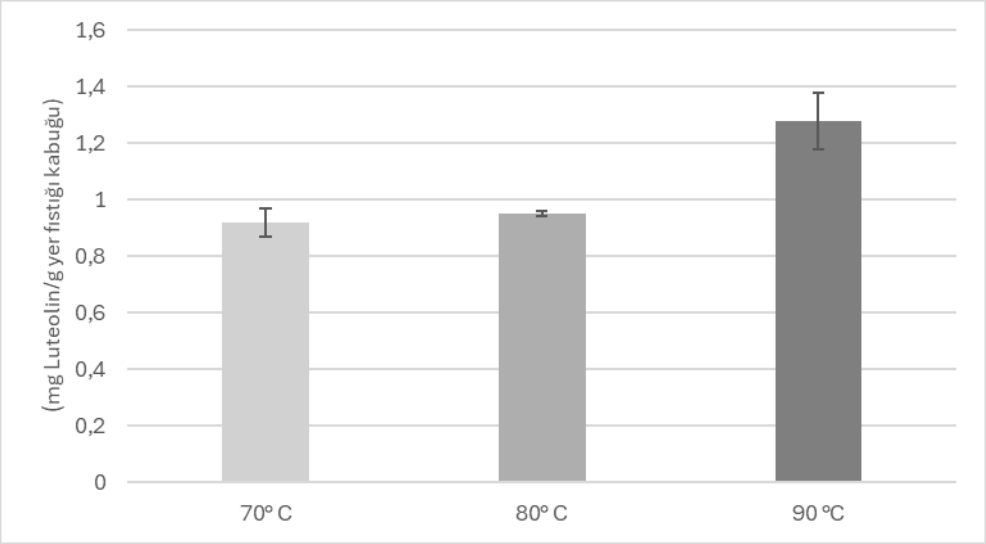
Sıcaklık Etkisi

Şekil 5'te sıcaklık parametresi 70, 80 ve 90 °C olarak değerlendirilmiş; tuz konsantrasyonu ve pH sabit tutulmuştur. Yapılan analizler, en yüksek toplam fenolik madde miktarının 90 °C'de elde edildiğini göstermektedir. El-Abbassi ve arkadaşları (2014), yaptıkları çalışmada zeytin işleme atık suyundan polifenol elde etmek için bulutlanma noktası ekstraksiyonu yöntemini kullanmıştır. Ultrafiltrasyon ile berraklaştırılan örneklerde, %10 Triton X-100 ile 90 °C'de 30 dakikalık bulutlanma noktası ekstraksiyon işlemi sonucunda %66,5 verim elde edilmiştir. CPE yöntemi, düşük yüzey aktif madde tüketimi ve gıdalara doğrudan entegrasyon imkânı gibi avantajlarıyla öne çıkmaktadır.



Şekil 5. Sıcaklığın toplam fenolik madde miktarına etkisi

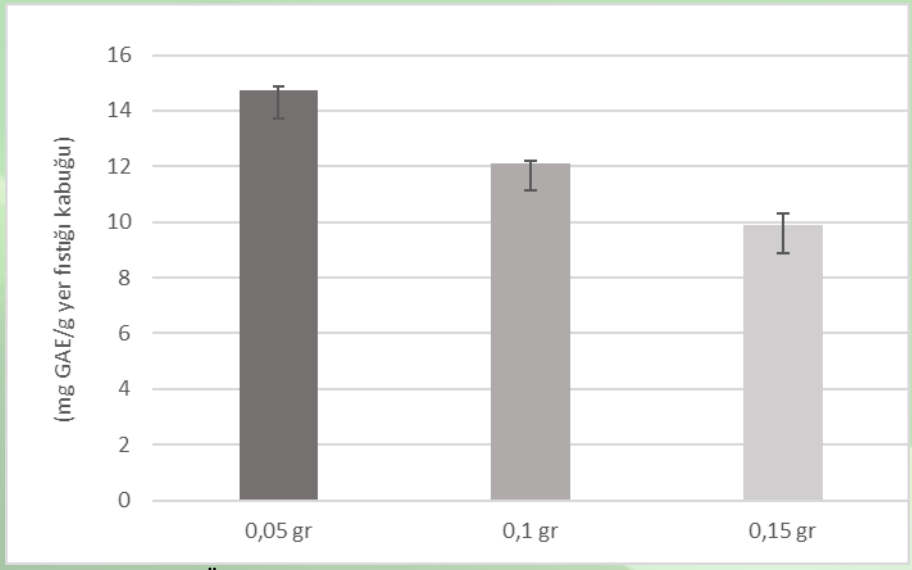
Şekil 6'da sıcaklık parametresi 70, 80 ve 90 °C olarak değerlendirilmiş; tuz konsantrasyonu ve pH sabit tutulmuştur. Yapılan analizler, en yüksek toplam fenolik madde miktarının 90 °C'de elde edildiğini göstermektedir. Benzer şekilde Mai ve arkadaşları(2020) yaptıkları çalışmada flavonoidlerin ekstraksiyon verimini etkileyen başlıca parametreler olan ekstraksiyon sıcaklığı (35–95 °C) ve süresi (5–25 dakika) incelenmiştir. Elde edilen bulgular, ekstraksiyon sıcaklığı 95 °C'ye ve süre 15 dakikaya kadar artırıldığında flavonoid veriminin anlamlı şekilde yükseldiğini göstermektedir. Ancak, daha uzun süreli ve yüksek sıcaklıklardaki ekstraksiyonlar, flavonoidlerin bozunmasına veya yapısal dönüşümüne neden olabileceğinden, optimum ekstraksiyon süresi 15 dakika olarak belirlenmiştir. Cihazın teknik sınırlamaları ve aşırı ısınmanın yol açabileceği zararlar göz önüne alınarak, sonraki deneylerde ekstraksiyon sıcaklığı 90 °C olarak belirlenmiştir.



Şekil 6. Sıcaklığın toplam flavonoid madde miktarına etkisi

Örnek Miktarının Etkisi

Şekil 7'de, örnek miktarının (0,05; 0,10 ve 0,15 g) biyoaktif bileşik kazanımı üzerindeki etkisi değerlendirilmiş; bu süreçte tuz konsantrasyonu ve pH değeri sabit tutulmuştur. Yapılan analizler sonucunda, en yüksek biyoaktif bileşik kazanımının 0,05 gram örnek miktarında elde edildiği belirlenmiştir. Bu durum, örnek miktarının artmasıyla birlikte sistemdeki çözünürlüğün sınırlanması ve kütle transferinin olumsuz etkilenmesi ile ilişkilendirilebilir. Katı/sıvı oranı arttıkça yer fıstığı kabuğundan su içerisinde fenolik madde çözünürlüğü doygunluğa ulaşır ve ekstraksiyon oranında düşüş meydana gelmektedir.



Şekil 7. Örnek miktarının toplam fenolik madde miktarına etkisi

Sonuç

Bu çalışmada yer fıstığı kabuğundan fenolik ve flavonoid bileşiklerin BNE yöntemi ile ekstraksiyonunda en yüksek fenolik bileşik miktarı %10 tuz konsantrasyonu ve pH 4 koşullarında elde edilirken en yüksek flavonoid bileşik miktarı %12 tuz konsantrasyonu ve pH 4,5 koşullarında elde edilmiştir. Sıcaklık parametresi için ise, 90 °C'de en yüksek fenolik ve flavonoid madde kazanımı sağlanmıştır. Örnek miktarı açısından ise, uygulanan BNE koşullarında 0,05 gram örnekle en fazla biyoaktif bileşik elde edilmiştir. Bu sonuçlar, BNE yöntemiyle yer fıstığı kabuğundan fenolik ve flavonoid bileşiklerin verimli bir şekilde elde edilebilmesi için işlem koşullarının dikkatle seçilmesi gerektiğini göstermektedir. Bulutlanma noktası ekstraksiyonu, yer fıstığı kabuklarından fenolik ve flavonoid bileşiklerin geri kazanımında etkili, düşük enerji tüketimli ve çevre dostu bir yöntem olarak öne çıkmaktadır. Bu yöntem, yer fıstığı kabuklarının değerlendirilerek hem ekonomik katma değer yaratılmasına hem de sürdürülebilir ve çevreye duyarlı üretim süreçlerinin geliştirilmesine katkı sağlayabilir.

Teşekkür

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Serum Selenium Levels in Dromedary Camel (*Camelus dromedarius*) Orally Supplemented with Sodium Selenite and a Mixture of Sodium Selenite and Sodium Sulphate

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Abstract

Deficiency of selenium might occur due to their low intake and impaired bioavailability. No data were available concerning the exact selenium requirements in camels. Selenium and sulphur have similar physical and chemical properties, and a number of studies indicate that increased dietary sulphur reduces the bioavailability of selenium. The present study was carried out on 12 young male and female clinically healthy dromedary camels (*Camelus dromedarius*), 2–3 years old were brought from Sodari area. Camels were housed collectively in one large pen at the animal housing of the Central Veterinary Research Laboratories, Soba, Sudan. They were left for four weeks for adaptation. The experiment was conducted in dry season. Animals were randomly divided into three groups of 4 animals each. The approximate mean weight is 185.28 kg. A control group, a group drenched daily with 4.4 mg of sodium selenite and a group drenched daily with a mixture of 4.4 mg of sodium selenite and 6 mg sodium sulphate anhydrous for three consecutive months. Blood samples were taken weekly and sera were analyzed. Selenium concentration was determined by using Inductively Coupled Plasma Spectrophotometer. Mean serum selenium levels in the control group were not significantly different at weeks 1, 3 and 8 to 12, whereas the values at weeks 2, 4 to 7 were significantly higher ($P<0.05$). In the group drenched with sodium selenite, significant differences ($P<0.05$) were shown. Low levels were observed at weeks 1, 2 and 3, whereas high levels were shown at weeks 11 and 12. Camels in the group drenched with the mixture showed significant differences ($P<0.05$). Low levels were observed at weeks 1 and 6, whereas high levels were observed at weeks 10, 11 and 12. It was concluded that camels are responsive to selenium supplementation. It could also be the mark of a greater sensitivity to toxicity.

Key words: *Selenium, dromedary, camel, Sulphur, serum.*

Introduction

Selenium (Se) received little attention from biologists for years but eventually was identified as the toxic principle that induced hair loss, lameness, hoof sloughing, and death in grazing livestock in South Dakota and Wyoming (Franke, 1934). Retrospectively, it was deduced that similar signs in horses observed by Marco Polo during his travels in China in the 13th century (Polo, 1926) and by Madison (1860) at Fort Randall, Nebraska Territory (a condition he called "alkali disease") were probably caused by Se toxicity.

The Se-deficiency problem in animal agriculture, as it existed before Se supplements could be legally used, has been reviewed (Ullrey, 1974). In some swine herds, mortality in growing pigs was 15 to 20% and morbidity was 25% or more. Reproductive efficiency was reduced and resistance to environmental stress and infectious disease was diminished. Comparable death losses and declines in productivity were observed in poultry and other livestock species. Selenium is an essential microelement for the prevention of a number of deficiency syndromes in a variety of species (Underwood, 1981). It is an antioxidant element. Its role in the body is not completely known. It is, however, involved in the absorption and/or retention of vitamin E. It is an integral component of glutathione peroxidase. Selenium, probably, has other essential functions in the enzymatic processes. In mammals, ingested Se-Met is absorbed in the small intestine via the Na^+-dependent neutral amino acid transport system (Vendeland et al., 1994). Higher animals are unable to synthesize Se-Met and only Se-Cys was detected in rats supplemented with Se as selenite (Tapiero et al., 2003).

The minimum daily allowance of selenium in most species is 0.1 ppm (mg/kg) on a dry matter (DM) basis (Maas, 1983). The requirement of selenium in ruminants is approximately 0.1 part per million (ppm) DM. The dietary Se requirements for camelids are probably similar to other ruminants (Fowler, 1986; Smith, 1989; Dart et al., 1996). An alfalfa hay based diet containing 0.2 ppm Se appeared to meet the Se requirement for llamas, based on glutathione peroxidase (GSH-Px) activity and the lack of clinical signs of selenium deficiency disease (Dart et al., 1996). In the Bolivian Altiplano, one of the nutrients most likely to be deficient for grazing llamas was Se (Espinoza et al., 1982). Although forage Se was deficient (0.06 ppm) in greater than 90% of samples, all llamas sampled were considered to have adequate liver Se concentrations. Iatrogenic Se toxicity has been reported in a llama (Farrar et al., 1992), and Se toxicosis is possible due to excessive supplementation, in animals grazing pastures contaminated with Se-accumulating plants, and in areas where soils are high in Se (Fowler, 1989). Dietary Se greater than 1.5 ppm may produce Se toxicosis, especially if this amount is fed for an extended time (Pugh, 1993).

Material and Methods

Animals

Twelve young male and female camels (*Camelus dromedarius*) 2-3 years old were brought from Sodari area, North Kordofan. Animals were grazing and browsing naturally in Sodari area, North Kordofan State. The weights of the animals ranged between 147.74 and 217.40 kg. In the present work body weights were estimated according to Schwartz, et al. (1983). The weights of the animals were estimated every month in the morning before feeding, watering and selenium supplementation. They were housed collectively in one large pen at the animal housing of the Central Veterinary Research Laboratories, Soba. They were fed on sorghum (Abu Sabeen) hey and provided with water ad. libitum. They were left for four weeks before the experiment commenced for adaptation. During this period they were treated with Ivermectin (Kepromec, Kepro B.V., Holland) at a dose rate 0.2 mg/kg. b. wt. (1 ml/50 kg. b. wt.). Before the start of the experiment all animals were examined clinically for their freedom from external and internal parasites. The experiment was conducted in dry season from 15 February 2009 to 15 June 2009.

Experimental work

The experiment (182 days) consisted of three phases:
Adaptation period (days 1-60). During this stage, the animals received the basal diet without any mineral supplementation to equilibrate their mineral status. They did not receive any selenium supplementation.
Supplementation period (days 61-151). Animals were randomly divided into three groups of 4 animals each. The approximate mean weight is 185.28 kg. Approximate mean weights of the animals in each group were 741.11 kg.

- ***Control group:*** didn't receive oral selenium.
- ***Group orally drenched with*** 4.4 mg of selenium daily in the form of sodium selenite (Oligoselen Vitamine E, COOPHAVET, ANCENIS Cedex, France).
- ***Group orally drenched with*** 4.4 mg of selenium daily in the form of of a mixture of sodium selenite and 6 mg sulphur in the form of sodium sulphate anhydrous (Na_2SO_4) (Blulux Laboratories Ltd., INDIA-121001).

The selenium and the mixture of selenium and sulphur were drenched at 9 o'clock am. daily.
Post-supplementation period (days 152-182). During this last phase of the experiment, selenium supplementation was discontinued. Animals received the basal diet only.

Blood samples

Blood samples were collected from the jugular vein in non-heparinized tubes (NH) at 9 o'clock am. daily, centrifuged, the sera were separated, transferred to the Departments of Biochemistry, Central Veterinary Research Laboratories, Soba, and stored at -80°C.

Laboratory analysis

Selenium was done in Animal Health Research Institute, Egypt by using ICP Spectrometer. Sera samples were digested by the use of Microwave method and run by ICP against known concentration of selenium**.** Quantification of selenium was performed by the standard addition method, using 11 point standard curve. AccuTraceTM Reference Standard solutions used were Quality Control Standard #1AccuStandard® and Laboratory Performance Check Standard AccuStandard®. The analysis of selenium required the digestion of the samples to destroy proteins and amino acids in order to release the molecules of Se related to proteins. The serum (2 ml) was mixed in the tubes of rotator's digester with 10 ml Nitric Acid (HNO_3) then 5 ml Perchloric Acid ($HClO_4$). The acids used in samples preparation were high purity grad. The tubes were placed in the rotator then introduced into Microwave digestion system using Milestone MLS-1200 MEGA, Italy. After cooling, digested sample was transferred to volumetric flask and stored in refrigerator until analysis. The same digestion protocol was followed for urine, and faecal sample. For selenium determination in different samples Inductively Coupled argon Plasma – Atomic Emission Spectrometer (ICP AES), Varian Vista MPX – CCD Simultaneous was used.

Statistical analysis

The data were introduced according to excel sheet and coded. The SPSS software version 10 was used for analyzing the data. One-way ANOVA was run. The separation of means when applicable was done using least significant difference (LSD), where P values higher than 0.05 were considered insignificant.

Results

The weekly mean values of serum selenium concentration in the group of camels orally dosed with 4.4 mg of sodium selenite daily for 12 weeks showed significant differences ($P<0.05$). The low levels were observed at weeks 1, 2 and 3 (35.39±2.43, 36.14±2.00 and 35.69±1.59 µg/l), respectively, whereas the high levels were

observed at weeks 11 and 12 (56.30±1.25 and 55.42±2.18 µg/l), respectively. The minimum level was at week 1 (35.39±2.43 µg/l), and the maximum level was at week 11 (56.30±1.25 µg/l). The weeks 4 to 6 recorded significantly higher (P<0.05) mean values than those at weeks 1 to 3, and significantly lower (P<0.05) mean values than those at weeks 7 to 12. The weeks 7 to 10 recorded significantly higher (P<0.05) mean values than those at weeks 1 to 6, and significantly lower (P<0.05) mean values than those at weeks 11 to 10 (Table 1 and Figure 1).

The weekly mean values of serum selenium concentration in the group of camels orally dosed with mixture of 4.4 mg of sodium selenite and 6 mg sulphur in form of sodium sulphate (Na_2SO_4) daily for 12 weeks showed significant differences (P<0.05). The low levels were observed at weeks 1 and 6 (45.39±1.85 and 46.68±1.89 µg/l), respectively, whereas the high levels were observed at weeks 10, 11 and 12 (67.23±3.87, 65.82±2.15 and 66.44±4.35 µg/l), respectively. The minimum level was at week 1 (45.39±1.85 µg/l), and the maximum level was at week 10 (67.23±3.87 µg/l). The weeks 2, 3, 5 and 7 recorded significantly higher (P<0.05) mean values than those at weeks 1 to 6, and significantly lower (P<0.05) mean values than those at weeks 8 to 12. The weeks 8 and 9 recorded significantly higher (P<0.05) mean values than those at weeks 1 to 3 and 5 to 7, and significantly lower (P<0.05) mean values than those at weeks 10 to 12 (Table 1 and Figure 1).

Table 1: Changes in serum selenium concentration and range in parenthesis (ng/ml) in camels supplemented with selenium and a mixture of selenium and sulphur.

Weeks	Groups		
	Selenium*n=4	Selenium+Sulphurn=4	Controln=2
1	35.39±2.43$^{\alpha}$(32.35–38.28)	45.39±1.85$^{\alpha}$(42.75–46.69)	51.02±0.71$^{\alpha}$(50.51–51.52)
2	36.14±2.00$^{\alpha}$(33.96–38.78)	57.25±1.44$^{\beta\chi}$(55.58–58.61)	49.67±0.26$^{\chi}$(49.48–49.85)
3	35.69±1.59$^{\alpha}$(34.33–37.99)	56.94±1.37$^{\beta\chi}$(55.49–58.70)	50.82±0.62$^{\alpha}$(50.38–51.26)
4	44.80±0.96$^{\beta}$(43.64–45.85)	66.33±0.55$^{\varepsilon\phi}$(65.80–66.82)	50.54±1.39$^{\chi}$(50.56–50.58)
5	44.94±0.75$^{\beta}$(44.32–45.98)	56.34±1.72$^{\beta}$(54.04–58.11)	51.30±2.27$^{\chi}$(51.09–50.90)
6	44.70±4.23$^{\beta}$(40.85–48.88)	46.68±1.89$^{\alpha}$(43.96–48.11)	50.50±2.91$^{\chi}$(50.44–50.56)
7	51.74±1.14$^{\delta}$(50.24–52.81)	55.79±1.77$^{\beta}$(53.95–57.90)	50.58±0.85$^{\beta}$(50.18–50.98)
8	47.85±4.90$^{\beta\chi}$(41.27–52.50)	61.34±5.52$^{\chi\delta}$(53.79–65.70)	51.08±0.71$^{\alpha}$(50.58–51.58)
9	48.91±1.14$^{\chi\delta}$(47.78–50.49)	62.27±4.59$^{\delta\varepsilon}$(55.86–66.70)	51.54±0.97$^{\alpha}$(50.85–52.22)
10	50.61±0.06$^{\chi\delta}$(50.53–50.66)	67.23±3.87$^{\phi}$(61.50–69.96)	52.30±3.22$^{\alpha}$(50.02–54.58)
11	56.30±1.25$^{\varepsilon}$(54.95–57.72)	65.82±2.15$^{\delta\varepsilon\phi}$(63.30–68.56)	51.88±0.89$^{\alpha}$(51.25–52.51)
12	55.42±2.18$^{\varepsilon}$(53.50–58.54)	66.44±4.35$^{\varepsilon\phi}$(61.50–70.63)	51.82±1.00$^{\alpha}$(51.11–52.52)

Means in the same columns with different superscripts are significantly different at P<0.05. *n: Number of animals.

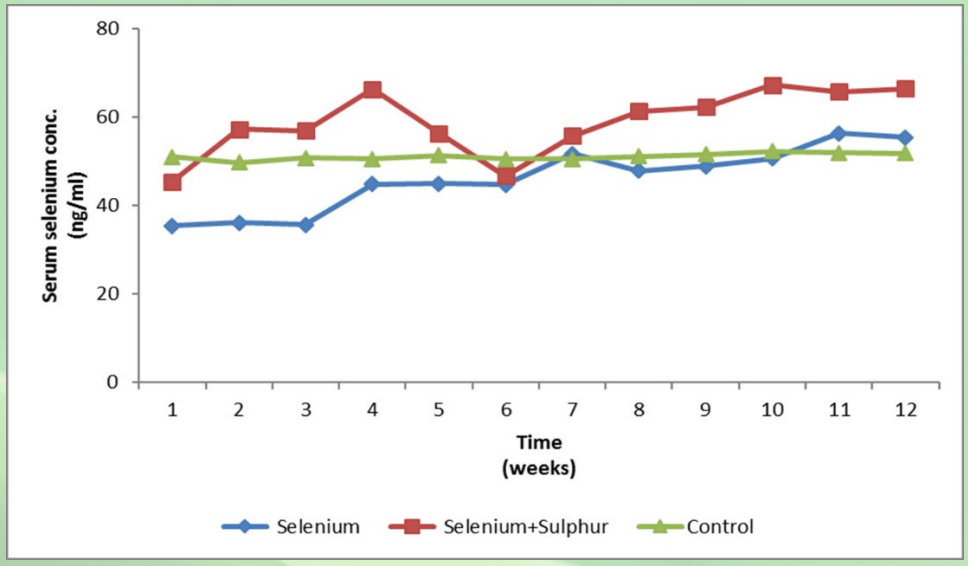


Figure 1: Weekly changes in serum selenium concentration in camels *(Camelus dromedarius)* orally suppleme

The weekly mean values of serum selenium concentration in the control group of camels were not significantly different at weeks 1, 3 and 8 to 12, whereas the values at weeks 2, 4 to 7 were significantly higher (P<0.05) (Table 1 and Figure 1).

Discussion

The mean concentration of blood/serum selenium reported in previous studies for large animals was around 100 ng/mL, a value considered as sufficient for the maintenance of suitable metabolic functions (Maas et al., 1990). In Saudi Arabia, serum Se values reported in young camels at the slaughterhouse varied between 5.3 and 131 ng/mL

with 30% of samples higher than 100 ng/mL (Barri & Al-Sultan, 2007). In recent experiments with different levels of Se supplementation, selenium content in serum for non-supplemented animals was on average 137.6 ± 18.7 ng/mL in non-pregnant, non-lactating camels (Seboussi et al., 2008), 109.3 ± 33.1 ng/mL in pregnant females, and 103.4 ± 28.7 ng/mL at milking period (Seboussi et al., 2009). Hamliri et al. (1990) observed in whole blood values between 109.1 and 117.8 ng/mL, Similar figures were recorded by Liu et al. (1994) in China, with concentrations varying from 97 to 112 ng/mL. Ma (1995) reported higher values: 274 to 288 ng/mL. In the United Arab Emirates (UAE), the mean value was 200 ± 90 ng/mL in animals with no Se supplementation (Seboussi et al., 2004). In small camelids such as llama (Herdt, 1995), the selenium concentration in serum ranged on average between 213 and 203 ng/mL depending on the physiological status. In Sudan, Abdel Rahim (2005) reported values in whole blood varying between 25 and 53 ng/mL. The analytical method used could also explain the observed differences. In Morocco, in dromedaries receiving probably a low Se basal diet, the plasma selenium concentration was quite lower, about 21 ng/mL (Bengoumi et al., 1998). In male adult camels in healthy conditions from Iran, the selenium concentration reported in serum was 12.6 ng/mL only (Nazif et al., 2009).
However, in most of the reported values, the selenium status of the diet was unknown even if Se supplementation was not distributed to the animals. Also, the analytical procedures were not described in all the cases and could differ between authors.

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Sürdürülebilir Hayvansal Üretim İçin Su Mercimeği Potansiyeli

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Özet

2050 yılına kadar 9 milyarın üstüne çıkması beklenen insan nüfusunun artışı iklim değişikliği ve kaynakların hızlı, bilinçsiz tüketilmesiyle birlikte, gıda sistemi üzerine insan kaynaklı baskı yaratacağı öngörülmektedir. Bu durum gelecek nesiller için besleyici gıdaların güvence altına alınmasını sağlayacak 'sürdürülebilir gıda sisteminin geliştirilmesini' zorunlu kılmaktadır. Bu sebeplerle hayvan beslemesi için alternatif ve sürdürülebilir bir protein kaynağı bulunmalıdır. Doğal kaynakların gelecek yıllarda tükenmesi tehlikesine karşı, artan yem maliyetleri nedeniyle özellikle ruminant hayvanlar için alternatif yem kaynaklarına ihtiyaç duyulacaktır. Su mercimeği (*Lemna minor)* yüksek protein içeriği, hızlı büyüme yeteneği ve sucul ortamlarda gelişebilmesiyle umut verici bir alternatif yem hammaddesi olarak öne çıkmaktadır. Su mercimekleri, su yüzeyinde yüzen ve boyutları 1.5 cm'ye kadar çıkan küçük bitkiler grubunu tanımlar. Su mercimeklerinin habitat gereksinimleri türler arasında farklılık gösterir ancak hepsi korunaklı, durgun suya ihtiyaç duyarlar. Bitki matının derinliği, bitkinin büyümesi için önemli bir sınırlayıcıdır. Su mercimeğinin dikkat çekici bir özelliği de muazzam bir üreme kapasitesine sahip olmasıdır. Elverişli koşullar altında, biyokütlelerini her 16 ila 48 saatte bir iki katına çıkardıkları bildirilmiştir. Su mercimeğinin alternatif yem hammaddesi olarak potansiyelini tam olarak gözlemleyebilmek için daha fazla araştırmaya ihtiyaç vardır. Diğer bir yandan su mercimeği temel amino asitleri içerir ve profili, geleneksel protein kaynaklarıyla karşılaştırılabilir yeterliliktedir. Ayrıca hızlı büyümesi, sık hasat imkânı sunarak sürdürülebilir, yenilenebilir ve ekonomik yem kaynağı sağlar. Geçmiş çalışmalarda su mercimeği yetiştirilmiş ve bitki %45 protein, %7 mineral, %37 karbonhidrat, %8 yağ ve %3 su içeriğine sahip olup, dokuz temel amino asit; demir, A, E ve B12 vitaminleri, omega 3, çinko, potasyum sağlamıştır. Bu projede, su mercimeğinin sindirilebilirliği ruminantlar üzerinde detaylı bir şekilde incelenecektir. Bu çalışmanın temel amacı, su mercimeğinin sindirilebilirliğini belirlemek ve ruminantlar için potansiyel bir yem kaynağı olarak kullanılabilirliğini araştırmaktır. Proje kapsamında su mercimeğinin sindirilebilirliği değerlendirilecektir.

Anahtar Kelimeler: *Su mercimeği (Lemna minor), Ruminant besleme, Alternatif yem kaynağı*

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Evaluation of Some Element Contents in *Hypericum scabrum* L. from Kükürtlü Village (Erzurum)

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Abstract

Hypericum scabrum L. is a widely distributed plant in Turkey, known for its significant medicinal properties. This plant has been investigated for its potential as an accumulator in environmental pollution studies. In this study, the elemental contents of *H. scabrum* and surrounding soil samples from Kükürtlü Village, Erzurum, were analyzed to assess its capacity for element accumulation. The samples were processed following standard procedures for elemental analysis, and measurements were made using an ICP-OES device. The results revealed that *H. scabrum* contained high levels of potassium (K) and calcium (Ca), while calcium (Ca), iron (Fe), and magnesium (Mg) were the most concentrated elements in the soil. *H. scabrum* accumulated more potassium (K) than the soil, but other elements, such as copper (Cu), lead (Pb), nickel (Ni), zinc (Zn), and manganese (Mn), were found at lower levels. Although the plant's high uptake of macro-elements like potassium (K) may contribute to environmental nutrient recycling, its limited accumulation of certain heavy metals suggests that it has potential for mitigating environmental pollution, but it cannot be classified as a hyperaccumulator. Further studies should investigate the mechanisms of heavy metal uptake in *H. scabrum* and its potential for bioremediation in more detail.

Key Words: *Hypericum scabrum, element contents, Erzurum,* ICP-OES.

Kükürtlü Köyü (Erzurum)'nden Toplanan *Hypericum scabrum* L.'da Bazı Element İçeriklerinin Değerlendirilmesi

Özet

Hypericum scabrum L. Türkiye'de yaygın olarak bulunan ve önemli tıbbi özellikleri ile bilinen bir bitkidir. Bu bitki, çevre kirliliği çalışmalarında bir akümülatör olarak potansiyeli açısından araştırılmıştır. Bu çalışmada, Erzurum'un Kükürtlü Köyü'nden alınan *H. scabrum* ve çevresindeki toprak örneklerinin element içerikleri, element biriktirme kapasitesini değerlendirmek için analiz edilmiştir. Örnekler element analizi için standart prosedürler izlenerek işlenmiş ve ölçümler bir ICP-OES cihazı kullanılarak yapılmıştır. Sonuçlar, *H. scabrum*'un yüksek düzeyde potasyum (K) ve kalsiyum (Ca) içerdiğini, kalsiyum (Ca), demir (Fe) ve magnezyumun (Mg) ise topraktaki en yoğun elementler olduğunu ortaya koymuştur. *H. scabrum* topraktan daha fazla potasyum (K) biriktirmiş, ancak bakır (Cu), kurşun (Pb), nikel (Ni), çinko (Zn) ve manganez (Mn) gibi diğer elementler daha düşük seviyelerde bulunmuştur. Bitkinin potasyum (K) gibi makro elementleri yüksek oranda alması çevresel besin geri dönüşümüne katkıda bulunabilse de, bazı ağır metalleri sınırlı oranda biriktirmesi çevre kirliliğini azaltma potansiyeline sahip olduğunu, ancak hiperakümülatör olarak sınıflandırılamayacağını göstermektedir. *H. scabrum*'da ağır metal alım mekanizmaları ve biyoremediasyon potansiyeli daha ayrıntılı olarak araştırılmalıdır.

Anahtar Kelimeler: *Hypericum scabrum, element içeriği, Erzurum,* ICP-OES.

Introduction

The genus *Hypericum* Tourn. ex L., the largest genus of the Hypericaceae Juss. family, is represented by over 550 species worldwide (WFO, 2025). In Turkey, more than 100 species of this genus are found, with 48% of these species being endemic (Firat & Eroğlu, 2023). Members of *Hypericum*, which include trees, shrubs, annuals, and perennials, are widely distributed across various habitats, except for polar regions, tropical areas, and deserts (El-Chaghaby et al., 2024).

The material for this study, *Hypericum scabrum* L., has a wide distribution in Turkey and is naturally found in many regions, including Denizli, Kastamonu, Ankara, Erzurum, and Van (TÜBİVES, 2025). *H. scabrum* is a perennial plant that typically grows in dry and rocky slopes, open woodlands, and steppe habitats, at altitudes ranging from 750 to 3200 meters, and blooms between May and August (Peşin, 2007; Şerbetçi, 2002). A plant of significant medicinal value, *H. scabrum* has been used in traditional medicine to treat conditions such as heart, bladder, and intestinal disorders, rheumatism, jaundice, ulcers, gastritis, hemorrhoids, and constipation (Baytop, 1984). Its flowering branches are consumed in decoction form, while its fruits are used in infusions for stomach disorders (Kültür et al., 2018). In Turkey, it has been reported to be sold in markets for the treatment of eye diseases (styes) (Kocabaş et al., 2016). Recent studies have revealed that *H. scabrum* exhibits anti-inflammatory,

antioxidant, antifungal, and antidepressant effects, highlighting its potential for medicinal use (Abdollahi et al., 2012; Eslamı et al., 2011; Heshmati et al., 2018; Nalkıran Ergin et al., 2022; Şeker Karatoprak et al., 2019).
Industrial facilities are major sources of environmental pollution. As a result of production processes, heavy metals are released into the environment, with elements such as Pb, Ni, and Zn mixing into the atmosphere and soil, leading to severe environmental contamination. The accumulation of heavy metals in the soil can have toxic effects on organisms in the soil ecosystem, posing a threat to human health through the food chain. Heavy metal concentrations in soil typically range from 1 to 100,000 mg/kg, and when present at high levels, they disrupt the biological balance of the soil ecosystem, leading to reduced agricultural productivity and damage to ecosystems (Hayta & Avcil, 2019).

Previous studies have suggested that certain *Hypericum* species may exhibit potential accumulator properties with respect to heavy metal accumulation (Ayan et al., 2010; Colak et al., 2020). In one study, the heavy metal contents of soil samples around the Bitlis Solid Waste Integrated Disposal Facility were analyzed, revealing a high accumulation of metals, particularly Zn, Pb, Fe, and Cu. As a result, it was indicated that *H. scabrum* could potentially act as an accumulator for specific heavy metals (Hayta & Avcil, 2019). However, further research is needed to understand the tolerance mechanisms of this species to heavy metals and to determine whether it qualifies as a hyperaccumulator. This study aims to evaluate the elemental content of *H. scabrum* by analysing the concentrations of various elements in plants collected from an area near a cement factory and in soil samples taken from the same area.

Materials and Methods

Plant and soil samples were collected from Kükürtlü Village (Aşkale, Erzurum) (Table 1, Figure 1).

Table 1. Locality Information of Collected Plant and Soil Samples

Locality	Altitude	Coordinate
Kükürtlü Village, Aşkale, Erzurum	2006 m	39º51'34"N-40º36'11"E

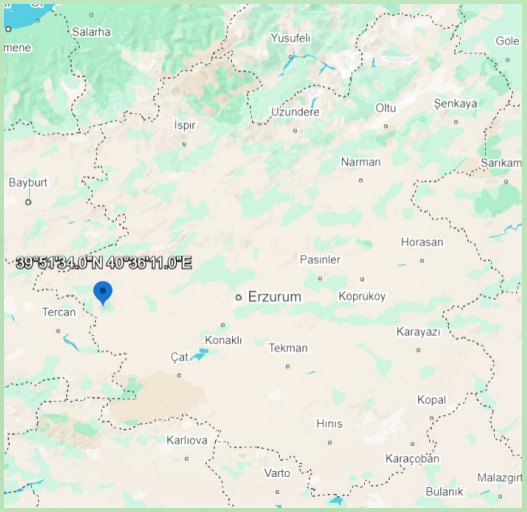


Figure 1. Location of the Plant and Soil Sample Collection Area (Google Earth)

The plant samples were carefully placed in polyethylene bags for preservation. Additionally, soil samples were also collected from the areas where the plants were gathered (Figure 1). To prevent microbial degradation of the plant material and to establish a fixed reference value based on dry weight, all samples were dried in an oven at 80 °C for 24 hours. To ensure the homogeneous distribution of metal content in the samples, plant samples were ground using a micro mill and passed through sieves of specific sizes to prepare them for analysis. The soil samples were collected using a stainless steel auger, air-dried, and then sieved through a 2 mm mesh. The homogenized soil samples were placed in transparent paper bags for preservation during the analysis process. Heavy metal analyses were carried out according to the method described by Aksoy et al. (2005), and the measurements were performed using a Varian Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES). The accuracy and measurement stability of the device were evaluated by controlling internal standard contamination during digestion and analytical procedures for each sample.
Data for various parameters were subjected to one-way analysis of variance (ANOVA) using SPSS version 22.

Results and Discussion

In this study, the element contents of *H. scabrum* collected from Kükürtlü Village (Aşkale, Erzurum) and the soil samples from the same site were analyzed. The obtained results are presented in Table 2.

Table 2. Detected Element Concentrations in Plant and Soil Samples

Elements	Plant (mg/kg)	Soil (mg/kg)
Ca	4123.2 (±201.53)	72200 (±2633.27)
Cu	4.05 (±0.09)	36,248 (±31.94)
Fe	18.22 (±4.14)	126448.5 (±45497.37)
K	9725.05 (±13.47)	5253.15 (±96.95)
Mg	725.04 (±208.95)	21710.5 (±5974.345)
Mn	7.27 (±0.07)	3749.25 (±137.67)
Na	94.70 (±48.81)	3299.4 (±82.73)
Ni	1.14 (±0.05)	156.70 (±82.73)
Pb	4.10 (±4.16)	203.02
Zn	20.99	362.47

Element Concentrations in *Hypericum scabrum* and Soil

The analyses revealed that the elements found at the highest concentrations in *H. scabrum* were potassium (K: 9725.05 mg/kg), calcium (Ca: 4123.2 mg/kg), and magnesium (Mg: 725.04 mg/kg). In contrast, soil samples showed the highest levels of Ca (72,200 mg/kg), iron (Fe: 126,448.5 mg/kg), and Mg (14,761.13 mg/kg). These findings offer important insights into the uptake and bioavailability of elements from soil to plant tissues.

When comparing *H. scabrum* and soil samples, it was observed that K was present at a higher concentration in the plant (9725.05 mg/kg) than in the soil (5253.15 mg/kg). Although K is a macronutrient and not classified as a heavy metal, this suggests that *H. scabrum* has a strong ability to absorb K, which may contribute to nutrient cycling within the ecosystem. In contrast, the accumulation of other elements such as Ca, Cu, Fe, Mg, Mn, Na, Ni, Pb, and Zn in the plant was relatively limited.

Accumulation of Potentially Toxic Elements

From an environmental perspective, the plant samples contained low levels of potentially toxic metals such as Cu (4.05 mg/kg), Pb (4.10 mg/kg), and Ni (1.14 mg/kg). However, the soil samples showed relatively high concentrations of Pb (203.02 mg/kg) and Ni (156.70 mg/kg), suggesting that these elements have accumulated in the area.

These results point to the limited ability of *H. scabrum* to uptake and store potentially hazardous metals, despite their elevated presence in the soil.

Hyperaccumulation Potential of *Hypericum scabrum*

Hyperaccumulator plants are defined by their ability to accumulate certain heavy metals in their tissues at 10–100 times the concentration found in the surrounding soil. According to the literature, threshold values for hyperaccumulation vary by metal. For example, Cu, Ni, and Pb must exceed 1,000 mg/kg to qualify as hyperaccumulators (Farooqi et al., 2022), while Zn and Mn require levels above 10,000 mg/kg.

The low accumulation levels of Cu, Ni, Pb, Zn, and Mn in *H. scabrum* indicate that it does not meet the criteria to be classified as a hyperaccumulator for these elements.

Ecological Implications and Future Research

Despite its limited uptake of heavy metals, *H. scabrum* showed a notably high uptake of potassium (K), an essential macronutrient. Although K is not considered a heavy metal, its elevated concentration in plant tissue compared to soil suggests that *H. scabrum* may play a role in nutrient cycling and ecosystem function.

Overall, the findings of this study suggest that *H. scabrum* absorbs certain elements in limited amounts and cannot be considered a hyperaccumulator. Further research is recommended to better understand its elemental uptake mechanisms, evaluate its potential role in environmental monitoring or phytoremediation, and examine its responses under varying ecological conditions.

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Sustainable Irrigation Strategies for Enhancing Hass Avocado Yield in Arid Region of Tacna, Peru

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Abstract

Hass avocado production in the Tacna region of Peru faces challenges related to irrigation efficiency and water availability. Efficient water management is essential for improving tree growth, fruit yield, and economic sustainability. This study aims to evaluate the relationship between irrigation efficiency, soil moisture levels, and avocado productivity to identify key factors influencing sustainable production. A comparative analysis approach was used to assess soil moisture, irrigation efficiency, tree growth, and fruit yield across different regions. Data were collected through field measurements, including soil moisture at various depths, irrigation system performance, and tree development indicators such as height and stem diameter. Regions with higher irrigation efficiency demonstrated better tree growth and higher fruit yields. The tallest trees and widest stem diameters were observed in areas with optimal water management, while inefficient irrigation systems led to lower productivity. Economic analysis indicated that high irrigation costs in water-scarce regions posed financial challenges, but improved irrigation techniques enhanced profitability. Climate change and water scarcity were identified as major risks, emphasizing the need for precision irrigation and sustainable water management practices. Optimized irrigation and soil moisture management significantly improve avocado production. To ensure long-term sustainability, modern irrigation systems and efficient water use strategies should be prioritized in water-scarce regions.

Key words: Hass avocado, irrigation efficiency, soil moisture, fruit yield, water management, sustainable agriculture, precision irrigation.

ID: 612

Investigating The Phenotypic Traits And Probiotic Potential Of Lactobacillus Autochthon

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Abstract

The present study aimed to evaluate the biochemical and physiological characteristics, as well as the technological and probiotic properties of specific autochthonous Lactobacillus isolates. Initially, we confirmed the identification of these bacteria as belonging to the Lactobacillus genus by examining their macroscopic characteristics, conducting the catalase test, and performing Gram staining. Subsequently, we analyzed their biochemical and physiological traits, followed by an assessment of their technological properties. To evaluate their probiotic potential, we tested several of these isolates for antibacterial activity against a pathogenic strain of *Staphylococcus aureus* isolated from a urine sample of a patient with a urinary tract infection. The results indicated that most isolates are homofermentative and demonstrate the ability to thrive under challenging conditions. Additionally, the Lactobacillus strains exhibited strong acidifying, proteolytic, and lipolytic activities. They also produced flavors and exopolysaccharides (EPS), along with significant antibacterial properties. In conclusion, the Lactobacillus isolates assessed exhibited promising technological attributes that could be valuable in the food industry, particularly in dairy applications. Furthermore, their potential use in probiotic treatments, specifically for urinary tract infections, could provide a viable alternative to traditional antibiotic therapies.

Key Words: *Antibacterial activity, Lactic acid bacteria, Lactobacillus, probiotic effects, technological skills.*

ID: 614

Gene Deletions and Silencing via High Pressure Spraying Technique

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Abstract

Controlling gene expression is critical for improving resistance against biotic and abiotic stress factors. The introduction of expression vectors encoding artificial miRNA or larger hairpin RNA to crops has proven to be effective for higher crop yield and quality by silencing the target gene via the RNA interference (RNAi) mechanism. Similarly, CRISPR/Cas-based genome editing tools have been employed to rewire the transcriptome by deleting genes or regulatory elements for improved crop plants. The expression of RNAi inducers, Cas endonucleases, and guide RNAs all rely on the delivery of expression cassettes via agrobacterium-mediated plant transformation. However, legal regulations, negative public perception, and lengthy and laborious tissue culture requirements restrict the use of agrobacterium-mediated transformation of crop plants. In animal systems ribonucleoproteins (RNP) and RNAs are commonly used to circumvent the use of DNA and tissue culture to induce gene silencing or genome editing *in vivo*. However, cell wall appears as a major barrier preventing the delivery of RNP and RNA molecules into the plant cells. We developed the high-pressure spraying technique (HPST), which successfully delivered sRNAs, mRNAs, and RNP molecules into plant cells *in planta*. In addition, the use of carbon-based nanoparticles, such as carbon dots, improves the uptake efficiency. The delivery of these molecules led to DNA- and tissue culture-free genome editing methods, new methods in epigenetic plant breeding, and substantially faster applications of gene deletions via CRISPR/Cas. In this presentation, the power and the limitations of HPST for RNAi and gene editing will be discussed.

Key Words: *CRISPR/Cas, RNAi, Genome Editing, RNA delivery, Plant Breeding*

ID: 615

Bridging the Digital Divide: An Assessment of Agricultural Extension Personnel's Usage of Digital Technology in Ondo State, Nigeria

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Abstract

This study assessed the utilization of digital technologies by public agricultural extension agents in Ondo State, Nigeria, for disseminating agricultural information. Data were collected from all (60) the extension personnel working with Ondo State Agricultural Development Programme using a structured questionnaire. Data analysis was carried out using descriptive statistics (frequency distributions, means, percentages) and inferential statistics (Chi-square tests, Pearson Product Moment Correlation) to test the study's hypotheses. The results revealed that mobile phone (100%), social media platform (98.3%), e-mail and SMS messaging tools (98.3%) were most available digital tools. Social media platform ($\bar{x}$ = 6.97) and television and radio broadcast ($\bar{x}$ = 6.97) were mostly utilised digital tools by the extension personnel for extension service delivery. The majority (66.7%) of the respondents had high knowledge in the use of digital technology for their extension work. Unstable power supply ($\bar{x}$ =1.98, high cost of Information Technology gadgets ($\bar{x}$ =1.83) and inadequate income to undertake digital technology training ($\bar{x}$ =1.78) were major constraints to the utilization of digital technology. Also, significant relationship existed between respondents' knowledge of digital technology (r=0.660) and the usage of digital technology (r=0.660). The study concluded that majority of the extension personnel utilised digital tools at high level for documentation, dissemination and information gathering purposes. To enhance the effectiveness of digital technology in agricultural extension services, it is recommended to stabilize power supply and provide continuous training to improve digital literacy among extension agents.

Keywords: *Digital technology, agricultural extension, information dissemination, extension personnel*

ID: 619

The role and potential of in silico studies in medicinal plant research

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Abstract

In silico studies, which have become increasingly widespread, are a crucial tool in overcoming the limitations of laboratory facilities, the high costs of chemicals, and the equipment and time requirements encountered in medicinal plant research. These studies generate data by analyzing the chemical structures of target molecules and enzymes, utilizing various online servers, computational, and visualization tools. The data generated can support, predict, or validate laboratory operations. Based on structure-activity relationships and prior clinical and preclinical data, *in silico* studies offer valuable predictions. Online resources help ascertain the physicochemical and pharmacokinetic characteristics of molecules. Interaction analyses are performed by calculating binding energies and the stabilities of molecules. Furthermore, a variety of computational techniques are employed to predict biological activities. *In silico* predictions are generally consistent with data obtained from previous clinical and preclinical studies, playing a crucial role in medicinal plant research. The implementation of such studies should be promoted, as they contribute to cost reduction and time efficiency. This study presents several examples to support the wider use of *in silico* studies in medicinal plant research.

Key Words: *In silico, Binding energy, Molecular docking, ADME, Medicinal plants*

In siliko çalışmaların tıbbi bitki araştırmalarındaki yeri ve potansiyeli

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Özet

Günümüzde oldukça yaygınlaşan *in siliko* çalışmalar, tıbbi bitki araştırmalarında kısıtlayıcı faktör olarak karşımıza çıkan laboratuvar altyapısındaki sınırlamalar, yüksek kimyasal maliyetleri, zaman yönetimi ve gerekli ekipman gereksinimlerini aşmak için önemli bir araçtır. Bu çalışmalar, hedef molekül ve enzimlerin kimyasal yapılarının yanı sıra çeşitli hesaplama ve görselleştirme yazılımları ve çevrimiçi sunucular kullanarak veri üretir ve üretilen veriler laboratuvar faaliyetlerini desteklemek, tahmin etmek ya da doğrulamak amacıyla kullanılabilir. *In siliko* çalışmalar, önceki klinik ve klinik öncesi verilerle yapı-aktivite ilişkileri üzerinden tahminler yapmaktadır. Moleküllerin fizikokimyasal ve farmakokinetik özellikleri çevrimiçi araçlarla belirlenmektedir. Etkileşim analizleri, moleküllerin bağlanma enerjileri ve kararlılıkları hesaplanarak yapılmaktadır. Ayrıca, biyolojik aktiviteleri tahmin etmek için, çeşitli hesaplamalı yöntemler kullanılmaktadır. *In siliko* tahminler, daha önceki klinik ve klinik öncesi çalışmalardan elde edilen verilerle çoğunlukla uyumlu olup, tıbbi bitki araştırmalarında önemli bir rol oynamaktadır. Bu tür çalışmaların kullanımı, araştırma maliyetlerini düşürme ve zaman kazandırma açısından teşvik edilmelidir. Bu çalışmada, in silico çalışmalarının tıbbi bitki araştırmalarında daha yaygın bir şekilde kullanılmasını desteklemek amacıyla bazı örnekler sunulmaktadır.

Anahtar Kelimeler: *in siliko, bağlanma enerjisi, moleküler kenetleme, ADME, tıbbi bitkiler*

ID: 620

Cardioprotective Effects of *Crocus sativus* L. Against Doxorubicin-Induced Cardiotoxicity: A Review of Antioxidant and Anti-Apoptotic Mechanisms

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Abstract

Doxorubicin is a commonly utilized chemotherapeutic agent effective against a wide range of cancers. Nonetheless, its clinical utilization is considerably constrained by dose-dependent cardiotoxicity, potentially leading to irreversible cardiac injury and heart failure. The mechanisms of doxorubicin-induced cardiotoxicity are intricate and multifaceted, encompassing oxidative stress, mitochondrial dysfunction, apoptosis, and disruptions in calcium homeostasis.

In recent years, there has been a growing focus on natural compounds with cardioprotective properties. Crocus sativus (saffron) and its active components, notably crocin and safranal, have exhibited encouraging antioxidant, anti-inflammatory, and anti-apoptotic effects in multiple preclinical models. Numerous studies indicate that Crocus sativus may mitigate doxorubicin-induced cardiac damage by regulating redox balance, inhibiting apoptotic signaling pathways, and maintaining mitochondrial function.

This review aims to provide a comprehensive examination of the existing evidence regarding the cardioprotective properties of Crocus sativus and its bioactive constituents in relation to doxorubicin-induced cardiotoxicity. The review examines the molecular mechanisms involved, underscores the limitations of existing studies, and delineates future research directions and potential clinical applications.

Key Words: Doxorubicin, Cardiotoxicity, Crocus sativus , Natural cardioprotective agent, Oxidative stress Chemotherapy-induced cardiotoxicity

Doksorubisin Kaynaklı Kardiyotoksisiteye Karşı *Crocus sativus* L'un Kardiyoprotektif Etkileri: Antioksidan ve Antiapoptotik Mekanizmaların Derlemesi

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Özet

Doksorubisin, birçok kansere karşı etkili, yaygın olarak kullanılan bir kemoterapötik ajandır. Bununla birlikte, klinik kullanımı, potansiyel olarak geri döndürülemez kalp hasarına ve kalp yetmezliğine yol açan doza bağlı kardiyotoksisite ile önemli ölçüde sınırlıdır. Doksorubisin kaynaklı kardiyotoksisitenin mekanizmaları karmaşık ve çok yönlüdür ve oksidatif stres, mitokondriyal disfonksiyon, apoptoz ve kalsiyum homeostazındaki bozulmaları kapsar.

Son yıllarda, kardiyoprotektif özelliklere sahip doğal bileşiklere artan bir odaklanma olmuştur. *Crocus sativus* (safran) ve aktif bileşenleri, özellikle krosin ve safranal, birden fazla klinik öncesi modelde cesaret verici antioksidan, anti-inflamatuar ve anti-apoptotik etkiler sergilemiştir. Literatürde yer alan birçok çalışma, *Crocus sativus*'un redoks dengesini düzenleyerek, apoptotik sinyal yollarını inhibe ederek ve mitokondriyal işlevi koruyarak doksorubisin kaynaklı kardiyak hasarı hafifletebileceğini göstermektedir.

Bu çalışmada, *Crocus sativus*'un kardiyoprotektif özelliklerinin yanı sıra doksorubisin kaynaklı kardiyotoksisite ile ilişkili biyoaktif bileşenlerine dair mevcut kanıtların moleküler mekanizmaları incelenecek, mevcut çalışmaların sınırlamalarını vurgulanarak, gelecekteki araştırma yönlerini ve potansiyel klinik uygulamaları sunulacaktır.

Anahtar Kelimeler: *Doksorubisin, Kardiyotoksisite , Crocus sativus , Doğal kardiyoprotektif ajan , Oksidatif stres ,Kemoterapiye bağlı kardiyotoksisite*

ID: 621

Phenolic Compounds Found in Citrus Species

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Abstract

Citrus fruits contain many components that are beneficial for health, including minerals, vitamins, and dietary fibers. They are also the main sources of many bioactive compounds with disease-preventing properties, such as flavonoids and limonoids. Flavonoids are a group of pigments found in plants and are responsible for the coloration of flowers and fruits. Flavonoids are found in fruits and vegetables in our diet. The inedible parts of citrus fruits, such as the peel, juice, and pulp, are as rich in phenolic compounds as the edible parts of the fruit. Citrus peels and seeds are rich in phenolic acids and flavonoids, and the peels contain more flavonoids than the seeds. The waste parts of citrus fruits such as peel and seed are particularly rich in flavonoid and phenolic compounds, and these compounds have important health properties. Recycling of citrus waste, which is produced in millions of tons worldwide, has significant potential in terms of environment and economy. In particular, recycling of peels contributes to the prevention of chronic diseases as a natural antioxidant source, while extending the shelf life by reducing oxidation in foods. The phenolic and flavonoid content of citrus waste varies depending on the species, growing conditions and harvest time. The use of citrus waste in the food, cosmetics and pharmaceutical industries not only reduces environmental pollution, but also enables the development of value-added products in terms of health and nutrition.

Key words: *Citrus fruits, Phenolic compounds, Citrus waste*

Turunçgil Türlerinde Bulunan Fenolik Bileşikler

Özet

Turunçgiller mineraller, vitaminler ve diyet lifleri de dahi olmak üzere sağlık için yararlı birçok bileşeni içermektedir. Ayrıca flavonoidler ve limonoidler gibi hastalık önleyici özelliklere sahip birçok biyoaktif bileşenlerin başlıca kaynaklarıdır. Flavonoidler bitkilerde bulunan bir pigment grubu olup çiçek ile meyvelerin renklendirmesinden sorumludur. Flavonoidler diyetimizde bulunan meyve ve sebzelerde bulunurlar. Turunçgillerin yenmeyen kısımları da kabuk, meyvenin öz suyu ve posası gibi meyvenin yenilebilir kısımları kadar fenolik bileşikler açısından zengindir. Narenciye kabuğu ve çekirdekleri fenolik asitler ve flavonoidler bakımından oldukça zengin olup, kabuklar flavonoid içeriği açısından tohumlara göre daha fazla bileşik içerir. Turunçgillerin kabuk ve çekirdek gibi atık kısımları, özellikle flavonoid ve fenolik bileşikler bakımından oldukça zengindir ve bu bileşikler sağlık açısından önemli özelliklere sahiptir. Dünya çapında milyonlarca ton üretilen turunçgil atıklarının geri dönüştürülmesi, çevresel ve ekonomik açıdan önemli bir potansiyel taşımaktadır. Özellikle kabukların geri kazanımı, doğal antioksidan kaynağı olarak kronik hastalıkların önlenmesine katkı sağlarken, gıdalarda oksidasyonu azaltarak raf ömrünü uzatmaktadır. Turunçgil atıklarının fenolik ve flavonoid içeriği; tür, yetiştirme koşulları ve hasat zamanına bağlı olarak değişiklik göstermektedir. Gıda, kozmetik ve ilaç endüstrilerinde turunçgil atıklarının kullanımı, çevre kirliliğini azaltmakla kalmayıp, sağlık ve beslenme açısından katma değerli ürünlerin geliştirilmesine de olanak sağlamaktadır.

Anahtar kelimeler: *Narenciye, fenolik bileşikler, narenciye atıkları*

Giriş

Narenciye türleri, dünyada yaygın olarak üretilmekte ve tüketilmektedir. En çok bilinen narenciye türlerinden portakal (Citrus sinensis) zengin antioksidan içeriği ile öne çıkarken, limon (Citrus limon) yüksek C vitamini içeriği ile bilinmektedir (Yüksekdağ, 2014). Mandalina (Citrus reticulata) daha tatlı ve az ekşi iken, greyfurt (Citrus paradisi) ise buruk tat vermekle birlikte zengin vitamin profiline sahiptir (Bürün, 2021). Turunç (Citrus aurantium) acı bir tada sahiptir ve genellikle marmelat yapımında kullanılır. Bu çeşitlerin yanında, lime (Citrus aurantiifolia) özellikle tropik bölgelerde sıkça tüketilen bir türdür (Özdemir & Tunçer, 2021).

Dünyada 2020/21 yılında yaklaşık 98 milyon ton narenciye üretilmiş olup bunların 49 milyon tonu portakal, 33 milyon tonu mandalina, 8 milyon tonu limon, 7 milyon tonu greyfurttur. Dünya turunçgil üretiminin kıtalara göre dağılımında Asya kıtası %44,9 ile birinci sırada yer almakta, Amerika kıtası %34,7 ile ikinci, Afrika kıtası %12,2 ile üçüncü sırada yer almaktadır (Atlı ve Söyler, 2018). Türkiye de ise 2020 yılında yaklaşık 4,3 milyon ton

turunçgil üretilmiş olup, bu üretimin %36'sı mandalina, %31'i portakal, %27'si limon ve %5'i greyfurta ait olmuştur. Turunçgil üretiminde Akdeniz bölgesi önde gelmekte olup mandalina üretiminin %84'ü, portakal üretiminin %85'i, limon üretiminin %93'ü, greyfurt üretiminin %96'sı bu bölgede gerçekleşmektedir (Turunçgiller Ürün Raporu 2021-333 TEPGE).

Turunçgiller, flavonoidler, fenolik bileşikler, askorbik asit, pektinler ve antioksidan maddeler gibi önemli biyoaktif bileşikleri bünyesinde barındırmaktadır (Fernández-López ve ark., 2005). Turunçgillerin bünyesinde barınan flavonoidler ve fenolik bileşikler; kalp hastalıkları riskini azaltmakta, bağışıklık sistemini güçlendirmekte, kanserojen hücrelerle savaşan antikorların üretimini desteklemekte, aynı zamanda antikanserojen, kolestrol düşürücü, antiinflamatuar ve antimikrobiyal etkiler göstermektedir (Zayed ve ark., 2021; Javanmardi ve ark., 2003; Elangovan ve ark., 1994; Friedman ve Levin, 2009). Narenciye meyvelerinin hem yenilebilen kısımları hem de özellikle kabuk gibi yenilmeyen bölümleri, zengin ve aktif bileşikler içermekte olup kabuklardaki yüksek flavonoid konsantrasyonu antimikrobiyal, antiviral ve antitrombotik gibi önemli biyolojik etkilere sahiptir. (Anagnostopoulou ve ark., 2006; Cook ve Samman, 1996). Flavonoidler, polifenolik yapıya sahip doğal bileşiklerdir ve meyve ile sebzelerin özellikle kabuklarında bulunurlar (Panche ve ark., 2016). Narenciye endüstrisinde kabuk ve çekirdek gibi atıkların geri dönüştürülmesi fenolik bileşiklerin için önemli bir kaynak oluşturabilir. Özellikle kabuklar, yenilebilir kısımlara kıyasla daha fazla fenolik bileşik içerir ve bu fark greyfurt, portakal, limon gibi türlerde belirgin şekilde görülür (Ma ve ark., 2009; Gorinstein ve ark., 2001). Gıda atıklarının geri kazanımı, çevresel sorunları azaltmanın yanında ekonomik faydalar da sunarak doğal kaynakların korunmasına yardımcı olur (Ajila ve ark., 2007; Hernandez-Carranze ve ark., 2016). Antioksidanlar açısından zengin gıdalar, kronik hastalık riskini azaltıp hücresel yaşlanmayı geciktirirken, gıdalara katılan antioksidanlar gıdalarda bozulmayı önleyerek raf ömrünü uzatır; turunçgiller ise önemli bir doğal antioksidan olan C vitamini bakımından oldukça zengindir (Boeing ve ark., 2012; Barden ve ark., 2016; Liu ve ark., 2012).

Turunçgiller mineraller, vitaminler ve diyet lifleri de dahi olmak üzere sağlık için yararlı birçok bileşeni içermektedir. Ayrıca flavonoidler ve limonoidler gibi hastalık önleyici özelliklere sahip birçok biyoaktif bileşenlerin başlıca kaynaklarıdır (Matheyambath ve ark., 2016). Flavonoidler bitkilerde bulunan bir pigment grubu olup çiçek ile meyvelerin renklendirmesinden sorumludur. Flavonoidler diyetimizde bulunan meyve ve sebzelerde bulunurlar (Macheix ve diğerleri, 1990). Turunçgillerin yenmeyen kısımları da kabuk, meyvenin öz suyu ve posası gibi meyvenin yenilebilir kısımları kadar fenolik bileşikler açısından zengindir (A.A. Damián ve ark., 2017; Mushtaq ve ark., 2014; Rodríguez ve ark., 2014). Narenciye kabuğu ve çekirdekleri fenolik asitler ve flavonoidler bakımından oldukça zengin olup, kabuklar flavonoid içeriği açısından tohumlara göre daha fazla bileşik içerir (Yusof ve ark.,1990). Turunçgillerin kabuk ve çekirdek gibi atık kısımları, özellikle flavonoid ve fenolik bileşikler bakımından oldukça zengindir ve bu bileşikler sağlık açısından önemli özelliklere sahiptir. Dünya çapında milyonlarca ton üretilen turunçgil atıklarının geri dönüştürülmesi, çevresel ve ekonomik açıdan önemli bir potansiyel taşımaktadır. Özellikle kabukların geri kazanımı, doğal antioksidan kaynağı olarak kronik hastalıkların önlenmesine katkı sağlarken, gıdalarda oksidasyonu azaltarak raf ömrünü uzatmaktadır. Turunçgil atıklarının fenolik ve flavonoid içeriği; tür, yetiştirme koşulları ve hasat zamanına bağlı olarak değişiklik göstermektedir. Gıda, kozmetik ve ilaç endüstrilerinde turunçgil atıklarının kullanımı, çevre kirliliğini azaltmakla kalmayıp, sağlık ve beslenme açısından katma değerli ürünlerin geliştirilmesine de olanak sağlamaktadır.

Turunçgiller ve Fenolik Bileşikler

Turunçgiller Geraniales takımının Rutaceae familyasının Aurantoideae alt-familyasına ait bir meyve grubudur (Antalya İl Tarım ve Orman Müdürlüğü, 2022) Birçok türü olmasına rağmen, ülkemizde en fazla tarımı yapılan turunçgiller sırasıyla, Citrus reticulata (mandalina), Citrus limon (limon), Citrus sinensis (portakal), ve Citrus paradisi (greyfurt)'dir (TÜİK, 2023).

Turunçgillerin ana bileşenleri; flavedo (dış kabuk), çekirdek (seed), meyve suyu kesecikleri (juice vesicles), albedo (flavedonun altındaki beyaz kısım), dilim (segment), dilim zarları (segment wall) gibi bölümlerden oluşmaktadır. Katmanlar incelendiğinde içeriğindeki bileşenler şu şekilde sıralanabilir

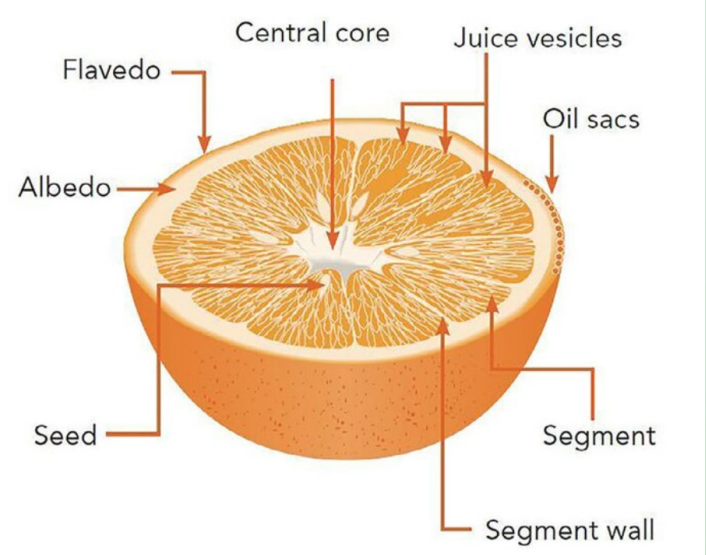
Flavedo (dış renkli kısım): flavonoidler ve esansiyel yağ (naringin ve limonen), pigmentler (karatenoidler), fenolleri içermektedir. Albedo (flavedonun altındaki beyaz kısım): protein, diyet, lifler, pektin, selüloz, neohesperidin içermektedir. Öz kalıntısı (meyve suyu ekstraksiyonundan sonra kalır): sitrik asit, folik asit, amino asit, selüloz içermektedir. Tohum: C vitamini, sterol, tokoferol, oleik asit, palmitik asit, limonoidler, eser mineraller içermektedir. (Chavan ve ark., 2018)

Turunçgiller; diğer meyvelerin bileşiminde yer almayan flavonon (hesperidin ve naringenin) ve karotenoid (kriptoksantin) bileşenlerinin ana kaynağıdır (Codoñer-Franch ve ark., 2010).

Meyvenin olgunlaşması esnasında meydana gelen çeşitli biyokimyasal ve fizyolojik değişimler yapıda yeni oluşumlara yol açar, örneğin; mandalinaların olgunlaşması sırasında karotenoid seviyeleri artar bu da rengin yeşilden koyu bir turuncuya kadar dönmesini sağlar. Aynı zamanda diğer biyoaktif bileşikler de değişir, bu durum meyvenin tadını ve asitliğini etkiler (Alquezar ve ark., 2008; Maduwanthi ve ark. 2019; Multari ve ark., 2020)

Narenciye bitkilerinden izole edilen ve tanımlanan 60'tan fazla flavonoid türü vardır. Narenciye kabuklarındaki flavonoidler, flavonon glikozitler (flavon C-glikozitler ve flavon O-glikozitler) ve polimetoksiflavonlar (PMF'ler)

olarak iki gruba ayrılmıştır (Zhang ve diğerleri, 2019). Flavonoidlerin temel yapısında bulunan benzoc–γ–piron (C6–C3–C6) glikozitleri birbirine bağlayarak oluşan flavon glikozitleri antikanser, nöroprotektif ve antiinflamatuar etkilere sahiptir (Musumeci ve ark., 2020; Okuyama ve ark., 2018). Hesperidin, turunçgil kabuklarında bol miktarda bulunan flavon O-glikozitlerine aittir. PMF'ler, C4 pozisyonunda bir karbonil grubu bulunan temel benzo-c-piron (15 karbonlu, C6–C3–C6) iskeletlerinde iki veya daha fazla metoksi grubu taşıyan flavonlardır. PMF'ler daha az polar ve yaklaşık düzlemsel yapıya sahiptir, bu da biyolojik membranlara yüksek geçirgenliğe yol açar ve kanda kolayca emilir (Gao ve ark., 2018). Metoksi gruplarının sayısı ve konumu, PMF'lerin biyolojik işlevleri üzerinde büyük bir etkiye sahiptir. Metoksi gruplarının artmasıyla, PMF'ler kanser hücrelerine yaklaşırken ve nüfuz ederken daha yüksek hidrofobisiteye sahip olur ve böylece daha güçlü biyolojik aktiviteye sahip olurlar (Walle, 2007). En yaygın olarak incelenen PMF'ler; tangeretin, nobiletin ve heptametoksiflavon ve bunların 5-hidroksile edilmiş PMF'leridir. Bazı hidroksillenmiş PMF'ler, PMF muadillerine göre daha güçlü anti-inflamatuar ve anti-kanser aktivitelerine sahiptir (Liu ve ark., 2021).



Şekil 1: Portakal meyvesinin genel bölümleri

(Adeniyi, A. G., Abdulkareem, S. A., Iwuozor, K. O., Ogunniyi, S., Abdulkareem, M. T., Emenike, E. C., & Sagboye, P. A. (2022). Effect of salt impregnation on the properties of orange albedo biochar. *Cleaner Chemical Engineering*, *3*, 100059.)

Flavonun dihidro türevleri ise flavanonlardır. En önemlileri naringenin, naringin, hesperidin ve hesperetin'dir. Naringin naringenin'in, hesperidin hesperetin'in glikozitidir. Greyfurt ve portakalda bol miktarda bulunurlar (Kökyar, 2012)

Turunçgil flavanonları glikozit veya aglikon formlarında bulunur. Aglikon formları arasında naringenin ve hesperetin en önemli flavononlardır. Glikozit formları arasında iki tip sınıflandırılır: neohesperidosidler ve rutinosidler (Gionfriddo ve ark.,1996; Macheix ve ark., 1990). Neohesperidosidler, flavanonlar, naringin, neohesperidin ve neoeriocitrin, neohesperidozlu bir flavanondan oluşurlar (ramnosil-a-1,2 glikoz) ve acı bir tada sahiptirler, rutinosidler (flavanonlar, hesperidin, nariru kalay ve didimin) ise bir flavanon ve bir disakkarit kalıntısı içerir. Flavanonlar genellikle diglikozit formunda bulunur ve turunçgillerin tipik tadını verirler (Macheix ve ark., 1990).

7-O-glikozilflavanonlar tüm turunçgillerde en bol bulunan flavonoidlerdir (Benavente ve ark., 1995; Lewinsohn ve ark., 1989). Neohesperidosid flavanonlar arasında naringin, neohesperidin ve neoeriositrin esas olarak bergamot, greyfurt ve acı portakal sularında bulunur. Rutinosid flavanonlar arasında hesperidin, narirutin ve didymin bergamot, portakal, mandalina ve limon sularında bulunur (Horowitz, 1986). Limon çekirdeği eriocitrin ve hesperidin, kabukları ise neoeriocitrin, naringin ve neohesperidin içermektedir. Kabukta neoeriocitrin ve naringinler benzer konsantrasyonda iken, çekirdekte; eriocitrin naringinden 40 kat daha fazla bulunmuştur (Tripoli ve ark., 2007). Bergamot çekirdeğinde naringin ve neohesperidin, ekşi portakal çekirdeğinde ise naringin tespit edilmiştir (Moulehi ve ark., 2012). Yapılan bazı çalışmalarda limon kabuğunun toplam fenolik içeriğinin, portakal ve greyfurt kabuklarından %15 daha fazla olduğu belirlenenirken (Gorinstein ve ark. 2001); greyfurt, limon ve portakal kabuklarının fenolik içeriğini inceleyen bazı çalışmalarda da greyfurt kabuğunda fenolik bileşik içeriği

daha yüksek bulunmuştur. İncelenen meyve kabuklarının fenolik içeriği farklılık göstermiş olup şu şekilde bir sonuca ulaşılmıştır: greyfurt 77,3 mg gallik asit eşdeğeri/g, limon 49,8 mg ve portakal 35,6 mg (Moulehi ve ark., 2012). Yine yapılan çalışmalarda bu kez greyfurt ve portakal kabuklarındaki toplam flavonoid içeriğinin limon kabuğuna göre daha yüksek olduğu görülmüştür. Kabukların flavonoid içeriği, greyfurt için 80,8 mg, portakal için 83,3 mg ve limon için 59,9 mg kateşin eşdeğeri/g olarak belirlenmiştir (Sir Elkhatim ve ark. 2018).
Yapılan çalışmalarda da görüldüğü gibi narenciye ürünlerindeki kabuk, pulp ve çekirdek gibi yan ürünlerin kimyasal yapısı ve antioksidan aktivitesi; narenciye çeşidine, yetiştirme koşullarına, iklime ve meyvenin hasat zamanına göre değişiklik göstermektedir (Karapınar ve Okuyan, 1982; Moulehi ve ark., 2012)
Tatlı portakal ve ekşi portakal flavonoid bileşikleri arasındaki farklar, tat profillerini etkileyen şeker türelerinden kaynaklanmaktadır. Tatlı portakallarda hesperidin ve narirutin, ekşi portakallarda ise neohesperidin ve naringin yoğun olarak bulunur (Bocco ve ark., 1998). Şekerlerden rutinoz (6-OaL-ramnosil-bD-glikoz), flavononlarlardan hesperidin ve narirutinin nötr tattan sorumludurlar ve tatlı portakallarda, mandalinalarda ve tangorlarda nispeten daha yüksek miktarlarda bulunurlar. Şeker neohesperidoz (2-OaL-ramnosil-bDglikoz), tangelolarda ve ekşi portakallarda yüksektir ve glikozitler neohesperidin ve naringine keskin veya acı bir tat verir (Peterson ve ark., 2006).
Çeşitli çalışmalar, bazı meyve çekirdeklerinin güçlü bir antioksidan aktiviteye sahip olduğunu göstermiştir. Narenciye meyvelerinde çekirdek ve kabuk bileşimleri her zaman aynı değildir. Örneğin, limon çekirdeği esas olarak eriositrin ve hesperidin içerirken, kabuk neoeriositrin, naringin ve neohesperidin açısından zengindir. Dahası, glikozit flavanon konsantrasyonları farklıdır; neoeriositrin ve naringin kabukta benzer konsantrasyonlara sahipken, çekirdekte eriositrin, naringinden 40 kat daha fazladır (Bocco ve ark., 1998). Neohesperidin, naringin ve neoeriocitrin büyük miktarlarda kabuktan elde edilir. Acı portakal çok ilginç bir neohesperidin ve naringin kaynağıdır; bu bileşikler tatlandırıcıların üretiminde faydalı olabilir. Bergamot tohumları, glikozlanmış flavanonlar, naringin ve neohesperidin'in en önemli kaynağıdır; limon eriocitrin ve hesperidin açısından zengindir. Diğer tüm turunçgil meyvelerinde az miktarda glikozlanmış naringin bulunur (Bocco ve ark., 1998; Yusof ve ark., 1990). Kabuk ve çekirdeklerin flavanon glikozil bileşimleri meyve sularınınkinden oldukça farklıdır. Naringin limon kabuğunda, limon çekirdeğinde ve mandalina çekirdeğinde bulunmuştur, ancak bu meyvelerin meyve sularında mevcut değildir (Mouly ve ark., 1995; Ooghe ve Detavernier, 1997).
Birkaç çeşitten elde edilen limon suyunda, glikozlanmış flavonoid miktarlarında çok az fark vardır. Eriocitrin, 6,8-di-C-b-glycosyldiosmin ve 6-C-b-glycosyldiosmin özellikle limon ve misket limonunda bol miktarda bulunurken, diğer turunçgillerde neredeyse hiç yoktur (Miyake ve ark., 1998). Polimetoksillenmiş favonlar (tangeretin, sinensetin, nobiletin, vb.) ve favanon glikozitleri (hesperidin, neohesperidin, narirutin, naringin, vb.) yalnızca turunçgillerde bulunur (M. Durand ve ark., 2015; Magwaza ve ark., 2016) . Hesperidin, neohesperidin, eriositrin, kuersetin, diosmin ve kaempferol, tatlı limonda temel fenolik bileşikler olarak bilinirken, rutin ve narirutin, minör bileşikler olarak bilinir. Kafeik, p-kumarik, sinapik, ferulik ve kloro-genik asit, tatlı limondaki en yaygın fenolik asitlerdir (Aludatt ve ark., 2017; Barreca ve ark., 2011; Hashemi ve ark., 2017; A.A. Damián ve ark., 2017; A. Fejzić ve ark., 2014) Kateşinler, lökoantosiyanin ve proantosiyaninler, diğer sebzelerde de bulunduğu için turunçgillere özgü bileşikler değildir (Tripoli ve ark., 2007).
Aşağıdaki tabloda portakal, mandalina, limon ve greyfurt meyve, kabuk ve çekirdeklerinde bulunan fenolik bileşikler verilmiştir.

Yapılan bir çalışmada mandalinanın kabuğunda toplam 28 fenolik bileşik tanımlanmıştır. Kabuk özlerinde, ana ürünler antosiyaninler, flavanonlar, flavanoller, flavonoller ve bir flavon (polimetoksile flavon sinensetin) dahil olmak üzere çoklu ikame desenlerine sahip flavonoidlerdi. Bunlar genellikle glikoz veya ramnoz veya arabinoz ile glikozillenmiş ve bazı durumlarda ayrıca diglikozillenmişti (rutin). İki fenolik asit (biri karşılık gelen aldehitle birlikte), bir dihidrokalkon (floretin) ve onun glikozillenmiş formu (floredzin) ve bir sinnamik asit (klorojenik asit) de bulundu. Polifenollere gelince, analiz kateşin-3-gallat (CG) ve epikateşin-3-gallat (EKG) ve tanen valoneik asit dilaktonun varlığını kanıtlanmıştır. Kabuğun fenolik bileşimi meyve olgunlaşma aşamasından güçlü bir şekilde etkilenmiştir. En ilginç aşama, en yüksek konsantrasyona ulaşan delfinidin-3-O glukozit, siyanidin-3-O-glukozit, delfinidin rutinozit, naringin, kuersetin-3-glukozit, rutin gibi bazı bileşikler için SRF gibi görünmektedir. (Costanzo ve ark., 2022)
Tohumlar arasında glikozile flavonların en ilginç kaynakları naringin ve neohesperidin açısından zengin bergamot; eriositrin ve hesperidin açısından zengin limon; ve naringin açısından zengin ekşi portakaldır. Diğer tüm türler çok az miktarda glikozile naringin içerir. Bu farklılıklar kullanılan meyvelerin çeşidine ve kökenine bağlı olabilir (Bocco ve ark., 1998).

Narenciye Atıklarının Kullanım Potansiyeli
Narenciye atıkları, değerli bileşenleri içeren yüksek organik madde konsantrasyonuna ve düşük pH değerine sahiptir (Zema ve ark., 2018). Sentetik antioksidanlar yerine doğal antioksidanların kullanımının önem kazanmasıyla birlikte, gıda işleme ve yan ürünlerinden antioksidan geri kazanımına yönelik çalışmalar artmıştır. Toplam meyve ağırlığının %50'sini oluşturan atıkların büyük bir kısmını narenciye endüstrisi üretmektedir.

Tablo 1. Portakal, limon, mandalina ve greyfurtun kabuk, meyve ve tohumlarında bulunan fenolik asitler ve flavonoidler

MEYVE	Bölge	Fenolik Asitler	Flavanoidler
PORTAKAL	Kabuk	p- kumarik asit (Wang ve ark. 2022) ferulik asit hekzozit ait, sinapik asit (Afifi ve ark., 2023)	sinensetin, narirutin, tetrametoksiflavon, nobiletin,hekzametoksiflavon (Guo ve ark., 2020) Hesperidin (Anagnostopoulou ve ark., 2006) Tangeretin ve nobiletin (Lu, Lee, Chu, Ho ve Sheen, 2019) Naringin, Limonin, Nomilin (Gou, 2014) apigenin, neohesperidin, naringin, isorhofolin, diosmin ve didymin (Anagnostopoulou ve ark., 2005)
	Tohum	Vanilik asit, kafeik asit, trans ferulik asit, p-kumarik asit (Falcinelli ve ark. 2020)	Eriocitrin, hesperidin, Didmin, Naringin, Narurutin (Berhow ve ark.,1998) Neoeriocitrin (Marini ve Balestireri, 1995)
	Meyve	ferulik asidi, p-kumarik asit, p-hidroksibenzoik asit (Fang ve ark. 2022) Klorojenik asit Kafeik asit (Hou ve ark. 2021; Xi ve ark. 2015)	Narirutin, Didmin (Forner-Giner ve ark. 2023) Naringin, Hesperidin, Epigallocatechin, Naftoresinol, Neohesperidin, Apigenin, Kuersetin, Rezorsinol, Kateşin, Rutin (Moulehi ve ark., 2012)
MANDALİNA	Kabuk	p-hidroksibenzoik asit, kafeik asit, vanilik asit, klorojenik asit, trans-sinamik asit (Anticona ve ark. 2022) gallik asit, ferulik asit ve p-kumarik asit (Gómez-Mejía ve ark. 2023)	Narirutin, hesperidin (Ma ve ark., 2008b) Nobiletin (Dou, 2019) Tangeretin, Sinensetin (Dou, 2019; Xu et al., 2019; Zhao et al., 2019) Limonin (Gou, 2014) Naringin, Naringenin, Apigenin, Kuersetin dihidrat, Rutin trihidrat, Kaempferol, (Anticona ve ark. 2022)
	Tohum	trans ferulik asit, p-kumarik asit, vanilik asit (Falcinelli ve ark. 2020)	hesperidin, naringin, narirutin ve tangeretin.
	Meyve	ferulik asidi, p-kumarik asit, p-hidroksibenzoik asit (Fang ve ark. 2022) Gallik asit, kafeik asit, klorejenik asit, vanilik asit, siringik asit, rosmanik asit, trans-2-Hydroxicinnamic acid (Moulehi ve ark., 2012)	Didymin, Eriocitrin, Hesperidin(Nogata ve ark. 1994) Epigallocatechin, Kateşin,Rutin,Kuersetin, Amentoflavon (Moulehi ve ark., 2012)
LİMON	Kabuk	gallik asit, ferulik asit ve p-kumarik asit (Gómez-Mejía ve ark. 2023) klorojenik asit, trans-ferulik asit (Alwazer ve ark., 2023)	Naringin (Büyükkurt ve ark., 2019; Patron- V´ azquez ve diğerleri, 2019) Nobiletin (Dou, 2019) Tangeretin (Dou, 2019; Xu et al., 2019; Zhao et al., 2019) Limonin (Gou, 2014) Narirutin (Chaves ve ark. 2022) Eriocitrin, neoeriocitrin, Neohesperidin, Luteolin, Isokuersitrin, Kuersetin galaktozit, Rutin, İzoramnetin, Rutinozit, Robinin, Mirisitrin (Rosa ve ark. 2023)
	Tohum	trans ferulik asit, ρ -kumarik asit, vanilik asit (Falcinelli ve ark. 2020) protokatekuik asit, ρ-hidroksibenzoik asit, siringik asit ve kafeik asit, sinapik asit (Dong ve ark., 2019)	Eriocitrin, hesperidin (Bocco, Cuvelier, Richard ve Berset, 1998).
	Meyve	Kafeik, p-kumarik, sinapik, ferulik ve klorogenik asit (Dong ve ark., 2019)	Hesperidin, Eriocitrin, diosmin, Cynaroside (Dong ve ark., 2019)
GREYFURT	Kabuk		Nobiletin (Dou, 2019) naringin (Büyükkurt ve ark., 2019; Patron- V´ azquez ve diğerleri, 2019) Limonin (Gou, 2014) Hesperidin, Eriocitrin, Diosmin, Sinarozit, Rutin(Dong ve ark., 2019) Didmin, Poncirin, Sinensetin (del Río ve ark. 2022)
	Tohum		Naringin(Büyükkurt ve ark., 2019; Patron- V´ azquez ve diğerleri, 2019) Nobiletin(Dou, 2019), Limonin (Gou, 2014),
	Meyve	protokatekuik, neoklorojenik asit, hidroksisinamik asitler ve ferulik asit (Cao ve ark. 2022) Klorojenik asit Kafeik asit (Hou ve ark. 2021; Xi ve ark. 2015)	Hesperidin, Neoeriocitrin, Neohesperidin (Deng ve ark. 2022) Narirutin, Naringin, Naringenin (Stabrauskiene ve ark. 2023) Cigranoside A-E, Bergamjuicin, Melitidin, Tangeretin, Heptametoksiflavon, Roifolin, Isokuersitrin (Deng ve ark. 2022)

Narenciye kabukları, doğal flavonoidler açısından oldukça zengin olduğu gibi, yenilebilir kısımlara oranla daha fazla fenolik bileşik içermektedir (Kökyar, 2012). Bu nedenle narenciye kabuklarındaki biyoaktif bileşiklerin potansiyeli, son yıllarda giderek artan bir ilgi görmüştür (Llorach ve ark., 2003; Manthey ve Grohmann, 2001). Narenciye atıkları, özellikle kabuk ve çekirdek kısımları biyolojik olarak aktif bileşikler açısından önemli bir potansiyele sahiptir. Bu atıklardan antioksidanlar, fenolik asitler ve flavonoidlerin geri kazanımı sayesinde, gıda, kozmetik ve ilaç sanayilerinde değerlendirme yapılabilir (Deng ve ark., 2012; Masuda ve ark., 2001). Ayrıca

antioksidanlar, gıda endüstrisinde raf ömrünü uzatmak ve oksidasyonu önlemek açısından kritik bir role sahiptir (Saito ve ark., 2004).

Gıda işleme sırasında ortaya çıkan atıkların etkin bir şekilde değerlendirilmesi yalnızca çevre kirliliğini önlemekle kalmaz, aynı zamanda katma değer yaratılması ve ürün çeşitlendirmesi açısından da büyük önem taşır. Atıkların değerlendirilmesi, ekonomik fayda sağlamanın yanı sıra, antioksidan ve diğer zenginleştirilmiş içeriklerin geri kazanımı sayesinde insan metabolizmasına girmesiyle sağlık ve beslenme açısından da ek faydalar sunmaktadır (Yağcı ve ark., 2006). Bitkisel atıkların geri dönüşümü, diyetlerde gıda takviyeleri, kozmetik ürünler ve sağlık odaklı ürünlerin üretimine yönelik çalışmalara odaklanmıştır. Narenciye atıklarından üretilen bu tür ürünlerin başlıca materyalleri sebze atıkları, meyve posası ve kabukları oluştururken, çekirdekler de son yıllarda bu alanda giderek popülerlik kazanmıştır (Peschel ve ark., 2006).

Sonuç

Turunçgiller, içerdiği fenolik bileşikler, flavonoidler ve antioksidanlar gibi biyoaktif maddelerle beslenme, sağlık ve endüstriyel alanlarda büyük bir öneme sahiptir. Meyvenin olgunlaşma süreci, bu bileşiklerin miktarı ve çeşitliliği üzerinde doğrudan etkili olup, renk, tat, asidite ve antioksidan aktivitede belirgin değişimlere yol açar. Fenolik bileşiklerin ve flavonoidlerin konsantrasyonu da olgunlaşma aşamasına bağlı olarak farklılık gösterir.

Narenciye atıklarının, özellikle kabuk ve çekirdek kısımlarının değerlendirilmesi ise sürdürülebilirlik açısından büyük bir potansiyel taşır. Bu atıklar, olgunlaşma süreçlerinde değişen fenolik bileşikler ve antioksidanların önemli bir kaynağı olarak gıda, kozmetik ve ilaç sanayinde kullanılabilir. Atıkların geri kazanımı, çevresel kirliliği azaltırken ekonomik katma değer sağlar ve doğal kaynakların korunmasına katkıda bulunur.

Sonuç olarak, turunçgillerin olgunlaşma aşamalarına bağlı olarak değişen biyoaktif bileşenlerinin takibi ve atık kısımlarının etkin değerlendirilmesi, sağlık, endüstri ve çevresel sürdürülebilirlik açısından önemli fırsatlar sunmaktadır. Narenciye türleri, zengin fenolik ve flavonoid içeriğiyla biyoaktif bileşiklerin önemli bir kaynağıdır. Yenilemeyen kısımların geri kazanımı, hem çevresel faydalar sağlayabilir hem de ekonomik açıdan cazip çözümler sunabilir. Gelecekte, bu atıkların etkin kullanımı için daha fazla çalışma yapılması gerekmektedir.

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Sausage and Shelf Life Studies

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Abstract

Humans have consumed meat throughout history, either processed or fresh, as the main source of nutrition. In the modern meat industry, emulsion meat products play an important role among meat products. It is known that meat has been traditionally prepared in dough since ancient times. In later periods, it developed and industrial production became widespread. Salami and sausage constitute common emulsion meat products. Emulsification of meat products is the binding of fat and water with the help of emulsifiers and meat proteins. Sausage in general terms; It is produced by adding various additives to the dough obtained by emulsification process from beef, pork, buffalo, poultry and sheep meat and by-products of these meats, and filling it into natural or artificial casings. Sausage is a product that is vulnerable to spoilage due to both being a meat product and the water and fat content in its structure. Various antioxidants and additives such as nitrate-nitrite salts are commonly used to extend the shelf life of sausage. In addition, studies have shown that the shelf life of sausages is affected by factors such as the antioxidant and antimicrobial substances used, the heat treatment and packaging technique applied, moisture content, storage temperature and microbiological load.

Key words: *Food emulsions, Meat products, Sausage, Shelf life*

Sosis ve Raf Ömrü Çalışmaları

Özet

Et tarih boyunca insanlar tarafından işlenmiş veya taze bir şekilde ana beslenme kaynağı olarak tüketilmiştir. Modern et endüstrisinde, et ürünleri içerisinde emülsiyon et ürünleri önemli bir rol oynamaktadır. Çok eski tarihlerden beri etlerin geleneksel olarak hamur şeklinde hazırlandığı bilinmektedir. Sonraki dönemlerde gelişerek endüstriyel üretimleri yaygınlaşmıştır. Salam ve sosis yaygın emülsiyon et ürünlerini oluşturmaktadır. Et ürünlerinin emülsifikasyonu temel olarak emülgatörler ve et proteinlerinin yardımıyla yağ ve suyun birbirine bağlanmasının sağlanmasıdır. Genel anlamda sosis; sığır, domuz, manda, kanatlı ve koyun etleri ve bu etlerin yan ürünlerinden, emülsifikasyon işlemi uygulanmasıyla elde edilen hamurun içerisine çeşitli katkı maddeleri katılıp, doğal veya yapay kılıflara doldurularak üretilir. Sosisin hem et ürünü olması hem de yapısındaki su ve yağ içeriğinden dolayı bozulmaya karşı zayıf bir üründür. Sosisin raf ömrünü uzatmaya yönelik çeşitli antioksidanlar ve yaygın olarak nitrat-nitrit tuzları gibi katkı maddeleri kullanılmaktadır. Ayrıca yapılan çalışmalarda sosislerin raf ömrünün kullanılan antioksidan ve antimikrobiyal maddeler, uygulanan ısıl işlem ve ambalajlama tekniği, nem içeriği, depolama sıcaklığı ve mikrobiyolojik yük gibi faktörlerden etkilendiği belirtilmiştir.

Anahtar kelimeler: *Gıda emülsiyonları, Et ürünleri, Sosis, Raf ömrü*

Giriş

Kırmızı et ve et ürünlerinin tüketimi insanlık tarihinden uzun bir geçmişe sahiptir. Et ve et ürünleri bir besin ve mükemmel bir protein kaynağıdır. Türk Gıda Kodeksi Et Ürünleri Tebliği'ne göre; "Et; sığır, manda, koyun, keçi gibi büyük ve küçükbaş hayvanlar; tavuk, hindi, kaz, ördek, beç tavuğu gibi evcil kanatlı hayvanlar ile tavşan ve domuzdan elde edilen, insan tüketimine uygun olan tüm parçalar" olarak tanımlanmaktadır. Et dünya çapında büyük bir ekonomiyi kapsamaktadır. Et besin olarak taze veya işlenmiş olarak farklı şekilde tüketilmektedir. İşlenmiş et ürünleri, taze ete göre daha uzun raf ömrüne sahip gıdalar üretme ihtiyacından dolayı geliştirilmiştir (Melro vd., 2020). Teknolojinin ilerlemesi, insan nüfusunun artması, hazır gıdalara olan talebin büyümesi ve insanların güvenilir gıda endişesi et ürünlerinin endüstriyel ölçekte üretilmesine olanak sağlamıştır. Böylece et ürünlerinin işlenmesi kolaylaşmış ve işlenmiş et ürün yelpazesi genişlemiştir.

İşlem görmüş et ürünleri olarak en çok sucuk, salam, sosis, pastırma ve kavurma tüketilmektedir (Kara, 2012). Et hamurları, etlerin diğer bileşenlerle birlikte esas olarak su, yağ ve proteinden oluşan kaba bir dağılım oluşturacak şekilde doğranmasıyla oluşturulur (Andrés vd., 2006). Sosis ve salamların hazırlanmasında işlenecek et çok küçük parçalar haline getirildiği için üründe bağlama sorunu ortaya çıkar. Bu nedenle bu tür ürünlerde emülsifikasyon işlemi kullanılır.

Su içinde yağ (oil/water) emülsiyonları, sulu bir fazda dağılmış bir yağ fazından oluşan sistemlerdir (Dickinson, 2009). Bu tür emülsiyon ürünlerinde dağıtılan faz genellikle yağdır. Su ise sürekli faz olarak içerisinde tuzları ve proteinleri içermektedir (Ertaş, 1998). Emülsiyon et ürünlerinde, ısıl işlemin ardından dağılmış emülsiyon damlacıkları, işlem sonrası üründe dolgu maddesi görevi görür (Santhi vd., 2017). Hamurun işlenmesi için kullanılan termal işlem, yüksek viskoziteli ürünü, yağ parçacıklarıyla dolu bir protein jeli olarak görülebilen viskoelastik bir katıya dönüştürür (Andrés vd., 2006). Emülsiyon ürünlerinde yaygın olarak tuz, fosfatlar, nitrit, dekstroz ve emülgatörler kullanılır.

Et emülsiyonları gerçek emülsiyonlar değildir, ancak et ve yağ parçalarının iki fazlı sistem halinde homojen karışımı olduğundan emülsiyon olarak nitelendirilir. Et emülsiyonları denilince esas olarak su ve hayvansal yağların et proteinleri ve emülsifiye edici ajanlar yardımıyla bir arada tutulması sağlanmaktadır. Et emülsiyonlarında kullanılan emülgatörler, tuzlu suda çözünebilen miyofibriller proteinler ve suda çözünebilen sarkoplazmik proteinlerdir (Anar, 2012). Et proteinleri arasında miyofibriler proteinler emülsifikasyonda yüksek işlevselliğe sahiptir. Farklı türler farklı protein özelliklerine sahiptir ve bu farklılıklar etkileşim etkilerinden kaynaklanabilir (Zorba & Kurt, 2006). Farklı türdeki ürünlerde et emülsiyonunun yapısı ve stabilitesi üzerine çalışmalar yapılmış ve yapılmaya devam edilmektedir (Youssef & Barbut, 2009).

Sosis

Emülsiyon teknolojisiyle üretilen et ürünleri ülkemizde büyüklük ve şekil bakımından "salam" ve "sosis" olarak sınıflandırılırken, dünya gıda sanayisinde genel terim olarak "sausage" (sosis) kullanılmaktadır. Sosisin kökeni tam olarak bilinmemektedir. Sausage kelimesi Latince kökenli olup tuzlanmış ya da tuz ile korunmuş anlamına gelen salsus kelimesinden köken almaktadır ve parçalanmış ya da kıyılmış etin tuzlama ile korunması anlamında kullanılmıştır (Anar, 2010). Salsus kelimesi aynı zamanda et ve kanın çeşitli katkı maddeleriyle karıştırılıp hayvan midelerine doldurulması ile elde edilen ürünler anlamında kullanılmıştır (Küçükarslan, 2023).

Sosisler, sığır eti, domuz eti, kümes hayvanları veya av hayvanı etinin öğütülmesi, tuz ve diğer baharatlarla karıştırılması ve ardından bir kılıfa doldurulmasıyla üretilir (Mohan, 2014). Sosisler şekil olarak yarım küre uçlu silindir şeklinde tanımlanır. Sosis ve salam tipi et ürünleri için, dünyada, standart bir sınıflandırılmaya gidilmiştir. Sosisler türlerine göre UK (Birleşik Krallık) tarzı taze sosis, pişmiş, fermente edilmiş ve emülsiyon sosis olarak sınıflandırmaktadır. Sosisler ısıl işleme göre; Çiğ sosis (Raw sausage, Rohwurst), Pişirilmiş sosis (cooked sausage, Brühwurst, Kochwurst), tipik özellik ve farklılıklarına göre; Jelleştirilmiş sosisler (Sülze) ve tamamen ezilmiş kıyma halindeki ürünler (minced meat product, Hackfleisch) olarak sınıflandırılmıştır (Akbulut & Karagözlü,2012). Emülsiyon tipi sosislere Bologna, kokteyl, Frankfurts, karaciğer sosisi vb. olarak örnek verilebilir (Essien, 2003).

Sosis için kullanılan genel tanımlama, tuz, baharatlar ve diğer bileşenlerle birleştirilmiş, belirli şekil ve büyüklükte bir kılıf içine doldurulabilen öğütülmüş veya doğranmış et ürünü şeklinde yapılabilir. Et kaynağı ve baharatlar, malzemeler ve/veya hazırlama yöntemi değiştirilerek çok çeşitli sosisler üretilebilir (Mohan, 2014).

Sosis ve salam üretiminde temel olarak aynı hamur kullanılmaktadır. Farklı katkı maddeleri kullanılması, et ve yağın az veya çok kuterlenmesi ve dolum yapılan kılıfların boyut ve biçim bakımından farklı olmasından kaynaklanmaktadır (Akşit, 2018; Gökalp, 1999). Fermente sucuklar hava kurutulduğundan olgunlaşmaları sırasında fire vermeleri söz konusudur. Fakat haşlanarak hazırlanan salam ve sosislerde %30 oranında su (buz şeklinde) katılarak hazırlanmaktadır (Anar,2012).

Sosis üretimi için hammadde seçimi

Et ürünleri üretiminde kullanılan hammadde olan et ve yağın yanında kürleme maddeleri, baharatlar, lezzetlendiriciler, bağlayıcı maddeler ve su kullanılmaktadır. Başarılı bir et ürünü formülasyonu elde etmek için üretimde kullanılan hammaddelerin ve katkı maddeleri ve bileşimleri hakkında bilgi sahibi olunmalıdır. Ayrıca kullanılan kürleme maddeleri, bağlayıcı maddeler ve dolgu maddelerinin oranları yasal düzenlemeler çerçevesinde formüle edilmelidir (Anar, 2012).

A. Et

Et ürünleri üretiminde dana, sığır koyun ve domuz etlerinin yanı sıra koyun eti, kanatlı etleri ve diğer etler ile çeşitli iç organlar da kullanılmaktadır. Etler hayvan türlerine göre ve karkastan elde edildikleri bölgelere göre rutubet, protein, yağ miktarı, renk su ve yağ bağlama yetenekleri yönünden farklılık göstermektedir. Üretilecek et ürününe göre et seçiminin yapılması bu nedenlerden dolayı önemlidir. Haşlanmış et ürünleri üretiminde hammadde olarak etin yanında yenilebilir iç organlarda kullanılmaktadır. Böylece ekonomik bir üretim yapılabilmektedir. Emülsiyon tekniği ile üretilen et ürünlerinde su bağlama kapasitesi denince etin suyu bağlama yeteneği ve yağları emülsifiye edebilme özelliği anlaşılır. Koyun etinin su bağlama yeteneği oldukça yüksektir ancak tüketiciler tarafından çok tercih edilmediği için üretilen ürünün %10 ila %20 oranlarında kullanımı sınır kalmaktadır (Anar, 2012).

B. pH

Etlerin pH değeri ve kimyasal durumları et teknolojisinde önemli faktörler arasındadır. Sosis gibi ürünlerin üretilmesinde sıcak et yani ATP oranı yüksek, pH 6.0 olan etler tercih edilmelidir. Bu tür etler diğer etlere göre %50 daha fazla tuzlu suda eriyebilir protein ekstrakte edebilir (Anar, 2012).

C. Yağ

Yağ et ürünlerinde önemli bir lezzet kaynağıdır. Yağ doğrudan etin tadına, yumuşaklığına ve gevrekliğine katkıda bulunur. Yağ emülsiyonda da görev almakta ve üretim maliyetini düşürmektedir. Genellikle etin yağlı olma durumuna göre %16-18 oranında yağ kullanılmaktadır (Anar, 2012).

D. Su

Sosis gibi emülsiyon et ürünlerinde su et hamurunun %20-30 oranında bu veya soğuk su şeklinde ilave edilir. Su emülsiyonun homojen olarak dağılmasını, proteinleri çözerek emülsiyona katılmasını, et hamuruna akıcı özellik verilmesini ve işlem sırasında sıcaklığı düşük tutarak emülsiyonun stabilitesinin korumasını sağlamaktadır (Anar, 2012).

E. Tuz

Et ürünlerinde tuz önemli bir kürleme maddesidir. Sosislerde genellikle %2 oranında tuz kullanılmaktadır. Tuz etin tadının oluşmasında, bakteriostatik etkisiyle gıdanın korunmasında, et proteinlerinin çözülerek emülsiyona katılmasında ve hamurun su tutma kapasitesinin arttırılmasında oldukça önemli rol oynamaktadır (Anar, 2012).

F. Nitrit

Nitrit sosis üretiminde arzu edilen renk oluşumu, kürlenmiş et ürünlerine özgü tat oluşumu ve antimikrobiyal etkisinden dolayı kullanılmaktadır. Ancak nitritin toksik bir bileşik olarak vücutta birikmesinden dolayı kullanımı maksimum 150mg/kg oranında sınırlandırılmıştır (Anar, 2012).

G. Şeker

Sosislerde tuzun tadını nötralize etmek ve kürlenmiş ürünlerin tadını arttırmak amacıyla % 0.4-1 oranında kullanılır (Anar, 2012).

H. Bağlayıcı ve dolgu maddeleri

Bu maddeler sosis hamurunda emülsiyon oluştuktan sonra fazla suyun absorbe edilmesiyle istenilen kıvam ve tekstürün oluşmasını sağlar. Sosis üretiminde sosislerin haşlanması sırasında şekil bozukluklarını önlenmesi ve maaliyeti düşürmesi nedeniyle de kullanılmaktadır. Bu ürünler çoğunlukla hububat unları ve nişastalar, sebze unları ve nişastası son olarak süt ürünleri olarak sıralanabilir (Anar, 2012).

İ. Fosfat

Fosfatlar kas proteinini çözmek için en etkili katkı maddesidir ve genellikle toplam kütlenin kilogramı başına 3-5 g fosfat kullanılır. Emülsifiye edilmiş sosisler için öncelikle difosfatlar içeren özel fosfat karışımları mevcuttur ve doğrama veya karıştırma-emülsifikasyon sırasında protein üzerinde hızlı bir şekilde etki eder. Bu önemlidir çünkü bir emülsiyon oluşturmak yalnızca 7-12 dakika sürer ve ikincil bir işlemde yağ ve suyu emülsifiye etmek için önce proteinin etkinleştirilmesi gerekir. Fosfatlar her zaman kesme işleminin başında eklenir, böylece protein üzerinde en başından itibaren etki edebilirler (Feiner, 2006).

Sosis üretimi

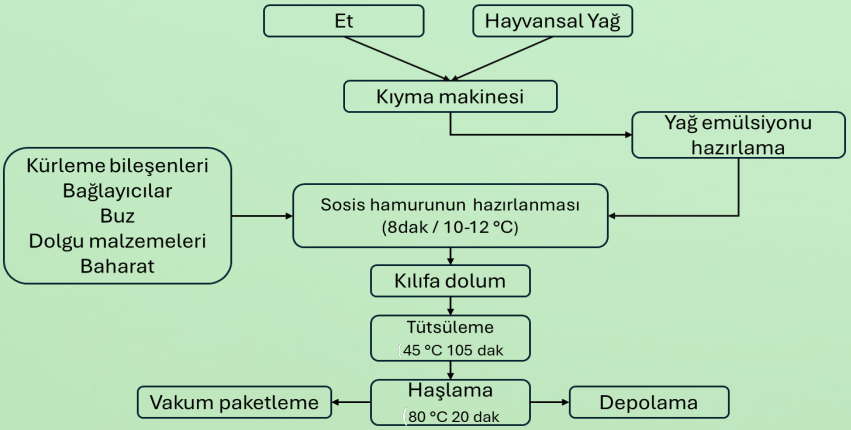
Sosis, protein ve tuzlar gibi çözünmüş maddelerin çözeltileri, ilave sudaki daha büyük parçacıkların süspansiyonları, kas proteinlerinden yapılan jeller ve protein ve yağdan yapılmış bir jel içinde stabilize edilmiş kısmen sıvı halde bulunan yağ içeren emülsiyonlar dahil olmak üzere farklı sistemlerin oldukça karmaşık bir karışımıdır. Ürün, yağ veya su ayrımı olmadan ısıl işleme dayanabilen, sağlam doku ve iyi kavrama gösteren, homojen, ince kesilmiş, pürüzsüz dokulu bir ürün olmalıdır (Feiner, 2006).

Genel olarak pişmiş bir sosis, emülsiyonda hiçbir yağ parçacığı görünmeyecek sürede kesilmeli ve aynı zamanda mümkün olduğu kadar fazla proteini aktive edilmelidir. Kesme veya emülsifiye etme işlemi çok kısa olursa eksik kesme meydana gelir; bu durumda yağ yeterince ufalanmaz ve son üründe gözle görülür parçacıklar görülebilir. Kısa bir kesme işlemi, optimum miktarda proteini aktive etmez ve bu nedenle, ısıl işlem sırasında büyük yağ parçacıklarını kaplayan yalnızca ince bir aktive edilmiş protein tabakası kalır. Bu, ısıl işlem sırasında yağ ve suyun ayrılması riskinin artmasına neden olur. Aşırı kesme, sosis kütlesinin çok uzun süre kesilmesidir ve bu, emülsiyondaki sayısız çok küçük yağ parçacıkları nedeniyle çok büyük bir yağ yüzey alanıyla sonuçlanır (Feiner, 2006).

Sosis üretim aşamaları;

- Etin kıyma haline getirilmesi
- Tuz, Baharatlar, katkı maddeleri ve buzun ilave edilmesi
- Kuterde boyut küçültme (3-5 °C)
- Yağ ilavesi
- Bağlayıcı (süt tozu veya soya proteini)
- Hamur kuterleme (15 °C)
- Kalan buz ekleme ve kuterleme
- Bağlayıcı (nişasta)

- Askorbik asit
- Hamur dolum makinesi
- Kılıflara doldurulma
- Ön kurutma (58-60 °C 10-20 dk)
- Dumanlama (65 °C 30 dk)
- Haşlama (80 °C 20 dk)
- Soğutma
- Su püskürtme
- Sıcaklığın 5 °C'nin altına düşürülmesi
- Askıda bekletme (suyun süzülmesi için)
- Ambalajlama
- Depolama



Şekil.1. Sosis üretim prosesi şematik gösterimi

Sosislerde raf ömrünü etkileyen faktörler ve bu konudaki bazı çalışmalar

Et, içerdiği mikroorganizmaların gelişimini destekleyen yeterli besin maddeleri açısından zengin bir ortam sunar ve çok çabuk bozulur; özellikle kıyma, karıştırma veya kıyma işlemi sırasında kolayca kirlenebilecek artan bir yüzey alanı mikrobiyolojik büyüme için eşsiz bir alan sunar (Mahami, T. vd., 2012). Sosis, kırmızı ete göre daha uzun raf ömrüne sahiptir. Ancak bu özelliği, gıda güvenliği riskleri içermediği anlamına gelmemektedir. Et işlenmeden önce ve işlendikten sonra farklı tehlikeler içermekte, dolayısıyla karkas ve kıymada farklı risk türlerinin ele alınması gerekmektedir (Karadal & Ova, 2020;Prayson 2008).

Günümüzde üretilen tüm sosislerin yaklaşık %85'ini oluşturan pişmiş sosisler de dahil olmak üzere, tüketime hazır et ürünlerine yönelik tüketici ilgisi giderek artmaktadır (Bohaychuk vd., 2006). Sosis üretiminde kullanılan teknoloji türünün, etten, sosis kılıfından, baharatlardan ve diğer bileşenlerden, çevreden, ekipmandan ve işleme sırasında işleyicilerden sosislere erişim sağlayan mikrobiyal kirletici maddelerin türünü etkilediği bildirilmiştir. Sosislerin kalitesinin ve özellikle güvenliğinin özünde üretim süreçlerinin mikrobiyolojisine bağlı olduğu söylenmektedir (Mahami, T. vd., 2012).

Sosisler su geçirmez kılıflarda -1 ile 4 °C arasında depolanır. Her ne kadar mikrobiyolojik açıdan 4 °C güvenli kabul edilse de depolama sıcaklıkları çoğunlukla 2 °C' nin altındadır çünkü 4 °C' nin altındaki her bir derece raf ömrünü büyük ölçüde uzatır. Su geçirmez kılıflar genellikle ambalaj görevi de görür ve ikincil ambalajlamaya gerek kalmaz, bu da ambalaj ve işçilik maliyetlerinden tasarruf sağlar. Porsiyonlara ayrılmış pişmiş sosisler genellikle vakumla paketlenir ve kapatılmadan önce 0,98 bar veya daha fazla tam vakumun uygulanması gerekir. Vakumlu paketleme, *Pseudomonas spp*. gibi aerobik bozulmaya neden olan bakterilerin gelişimini ortadan kaldırır. -1 ila 2 °C arasındaki düşük saklama sıcaklıklarıyla birlikte ürünün raf ömrünü artırır (Feiner,2006).

İşlenmiş et ürünlerinin raf ömrü ve fiziko-kimyasal özellikleri, formülasyona ve üretim süreçlerine bağlıdır. Yüzyıllar boyunca dünyanın farklı yerlerinde raf ömrü ve koruma için çeşitli teknikler geliştirildi (Melro vd., 2020). Sosislerin raf ömrünü etkileyen faktörler arasında özellikle hamur hazırlama, haşlama, dilimleme ve paketleme adımları oldukça etkilidir. Haşlamadan depolama ve teslimata kadar olan üretim adımlarında malzemelerin kalitesi, işlenmesi ve paketlenmesine kadar her prosesin özenle yürütülmesi gerekmektedir. Pişirme adımı nihai sosis ürününün raf ömrünü belirleyen en önemli parametredir (Entrup., 2005). Pişmiş sosislerin su içeriği yüksektir ve çabuk bozulur. Nihai ürünün tazeliğini arttırmak için çeşitli antioksidanlar ve antimikrobiyal katkı maddelerinin seçimi ve kullanılması da raf ömrünü uzatan etkenler arasındadır.

Et ve et ürünlerinin işleme, depolama ve raf ömrü sırasında lipid oksidasyonu, renk, tat ve tekstürde kalite kayıpları ile sonuçlanabilir. Sosis gibi emülsiyon tipi et ürünlerinde, emülsiyon stabilitesinin zamanla bozulması son üründe yağ ve su fazının ayrılmasıyla kalite üzerinde olumsuz sonuçlar doğurabilir. Sosislerin emülsiyon stabilitesinin artırılması raf ömrüne direkt etki edeceğinden stabil emülsiyon oluşturulması bu tip gıdalar için çok önemlidir (Aksel Efe, 2019). Hem birincil hem de ikincil lipit oksidasyon ürünleri tat, renk ve dokudaki değişikliklerin yanı sıra besin kalitesinin düşmesine de neden olur. Antioksidan ve antimikrobiyal özelliklere sahip doğal bileşikler, et ürünlerinin lipit oksidasyon hızını ve kalitesini etkileyebilir. Bitki sekonder metabolitlerinin en yaygın grubu olan polifenollerin et ürünlerindeki oksidatif reaksiyonlara ve mikroplara karşı etkili olduğu bildirilmiştir (Kalem vd., 2018; Zhang vd., 2017).

Et veya kümes hayvanları gibi işlenmiş gıda ürünleri, özellikle vakumla paketlenmiş sosisler, depolama süresi boyunca sızıntı oluşumuyla karakterize edilir. Gıda ürününden sızan bu sıvı, paketlenmiş gıdanın mikrobiyal kalitesinin yanı sıra duyusal özellikleri üzerinde de olumsuz etkiye sahip olabilir. Bu bağlamda, dışarı atılan sıvı, patojenlerin veya bozulmaya neden olan mikroorganizmaların çoğalmasına izin verir, çünkü dışarı atılan bu sıvı, karbonhidratlar, proteinler ve yağlar gibi makro besinler ve mikro besinler, yiyeceklerden ayrılabilir mikro mineraller ve suda çözünen vitaminler gibi makro besinler açısından zengin bir ortam görevi görür. Görünümün bozulması, bakteriyel bozulma ve sızıntıların kaybı sosislerin depolanmasındaki temel problemlerdir (Narasimha Rao & Sachindra, 2002; Saimaiti & Gençcelep, 2020).

Saffle, 1968'de, et emülsiyonları üzerine yayınlanmış araştırma verilerinin neredeyse tamamı 1960'tan beri yazıldığını ve et emülsiyonu alanının, fiziksel kimya, biyokimya, lezzet kimyası veya gıda bilimi konularında güçlü bir geçmişe sahip kişiler tarafından yapılması gereken gelecekteki araştırmalar için verimli bir alan olduğunu bildirmiştir.

Novaković vd., 2021'de yapılan çalışmada raf ömrü boyunca sosislerin antioksidan direnci arttırma ve oksidatif stresi azaltmaya yönelik sosis formülasyonuna arı poleni eklenmiştir. Çalışmanın amacı, sosislere farklı polen tozu konsantrasyonlarının (0.0, 0.5, 1.0 ve 1.5 g/100 g) eklenmesi ile sosisin kalitesine zarar vermeden, depolama sırasındaki antioksidan potansiyeli ve oksidatif değişiklikler üzerinde bir etkisinin olup olmadığını belirlemektir. Çalışma kapsamınsa Frankfurter sosislerin soğukta muhafazası sonrasında, kullanılan polen miktarı arttırıldığında (1.0 ve 1.5 g/100 g) psikrotrofik bakteri popülasyonunda önemli (P <0.05) azalmalar elde edildiği bildirilmiştir. Sosislere polen katılarak antioksidan özellikler iyileştirilmiş. Kalite parametreleri açısından istatistiksel olarak anlamlı değişiklikler elde edilirken, ürünlerin duyusal özelliklerinde herhangi bir bozulma yaşanmadığı tespit edilmiştir. Ayrıca polen ilavesi sosislerin doku profili analizleri açısından değişikliğe neden olmadığı bildirilmiştir.

Akbulut & Kuleaşan, 2022 bu çalışmada, konserve hindi sosisi üretiminde ısıl işlem ve depolama süresinin bazı kalite özelliklerine etkisinin araştırmak üzere koruyucu katkı maddesi kullanmaksızın hindi etinden üretilen sosislere 118 °C'de 50 dakika sterilizasyon işlemi uygulamıştır. 4 aylık depolama süreci boyunca mikrobiyolojik bozulmanın önlenmesi ve genel kalitenin korunması amaçlanmıştır. Çalışmada kullanılan çiğ hindi etinin başlangıç bakteri yükü 4.33 log kob/g olarak tespit edilmiştir. Isıl işlem sonrasında raf ömrü boyunca sosis örneklerinde mikrobiyolojik bir gelişmenin tespit edilmediği bildirilmiştir. Oksidasyon derecesinin belirlendiği tiyobarbitürik asit (TBA) analizinde ise, hindi sosislerinde istatistiksel olarak fark görülmediği bildirilmiştir ($P > 0.05$).

Ahmad vd., 2010 yaptığı çalışmada sosisin kalitesi ve raf ömrü değerlendirmesi için manda etine %0, 15 ve 25 seviyelerinde soya proteini izolatının (SPI) eklenmesi araştırıldı. Sosisin kalitesi pH, nem içeriği, tiobarbitürik asit (TBA) sayısı, toplam plaka sayısı (TPC) ve maya ve küf sayısı, duyusal, özellikler ve enstrümantal renk ve doku ölçümleri ile değerlendirilmiştir. pH ve nem içeriğinin az da olsa etkilendiği, TBA sayısının ise etkilenmediği bildirilmiştir. Sosisin taze örneğinin TPC'si 3,7–4,3 log kob/g aralığında tespit edilmiştir. Sosis panelistler tarafından kabul edilebilir seviyede olduğu görülmüştür.

Adams vd., 1987'de İngiliz taze sosisinin düşük oksijen geçirgenliğine sahip bir filmde (Diolon) vakumla paketlenmesi ve geleneksel paketleme yöntemi ile kıyaslanması üzerine çalışma yapılmıştır. Çalışmada geleneksel paketlerdeki 6°C'de 9-14 gün olan raf ömrü, filmle kaplı vakum paketleme yapılan üründe 20 günün üzerine çıkarıldığı bildirilmiştir. 10 günlük depolamadan sonra, mayalar ve Brochothrix thermosphacta gibi önemli bozulmaya neden olan organizmaların sayıları, vakumlu paketlerde genellikle 2 log döngüsü daha düşük olduğu tespit edilmiştir. Gözlenen raf ömrünün uzaması, vakum paketlerinde bozulma florasının büyüme hızındaki azalmaya ve bunun sonucunda inhibitör sülfit seviyelerinin daha uzun süre korunmasına atfedilmiştir.

Cegielska-Radziejewska & Pikul, 2004 ele aldıkları çalışmanın amacı, sodyum laktat ilavesinin hem hava hem de azot atmosferinde paketlenmiş ve soğutulmuş koşullarda saklanan dilimlenmiş kanatlı sosislerinin raf ömrünün uzatılması üzerindeki etkisini araştırmaktır. Mikrobiyolojik incelemede toplam aerobik psikrotrofik bakteri sayısı ve laktik asit bakteri sayısı belirlenmiştir. Dilimlenmiş kanatlı eti sosisinin mikrobiyolojik ve duyusal kalitesi, sodyum laktat üretimi sırasında eklenmesine ve paketlemede kullanılan gazların (hava veya azot) bileşimine bağlı olduğu ifade edilmiştir. %1 ve %2 sodyum laktat içeren kümes hayvanı sosisi dilimleri, uygulanan gazlardan bağımsız olarak, değerlendirilen duyusal özelliklerin başlangıçtaki kalitesini daha uzun süre koruduğu görülmüştür. Sodyum laktat, buzdolabında depolama sırasında aerobik psikrotrofik bakterilerin ve laktik asit

bakterilerinin büyümesini engellediği tespit edilmiştir. %1 ve %2 sodyum laktat ilavesinin, hava atmosferinde paketlenmiş ve 5 ila 7 °C'de saklanan dilimlenmiş kanatlı sosislerinin raf ömrünü sırasıyla 3 veya 4 kat uzatabileceği sonucuna varılmıştır. Azot içinde paketlenmiş %2 sodyum laktat ile muamele edilmiş dilimlenmiş kümes hayvanı sosisi, en uzun (35 günlük) raf ömrüne sahip olduğu belirlenmiştir. Bu, dilimlenmiş kümes hayvanı sosisinin raf ömründe kontrole kıyasla yedi kat artış olduğu bulunmuştur.

Hashemi vd., 2023 çalışma kapsamında, farklı konsantrasyonlarda resveratrol (RES: %0,002 ve %0,004) veya timol (THY: %0,5 ve %1) içeren, biyolojik olarak parçalanabilen sodyum aljinat filmleri hazırlamış ve bunların bozulmaya bağlı mikrobiyal profil üzerindeki etkileri değerlendirilmiştir. 4°C'de 40 günlük depolama sırasında sığır mortadella sosisinde lipit oksidasyonu, duyusal özellikler ve Listeria monocytogenes'e karşı koruyucu etkileri araştırılmıştır. Çalışmada %1 THY (tek başına veya farklı RES konsantrasyonları ile birleştirilmiş) içeren sodyum aljinat filmlerle sarılmış numunelerin, depolama süresinin sonunda diğer deney gruplarına kıyasla daha düşük bakteri sayısı sergilediği tespit edilmiştir. %0,004 RES ve farklı THY konsantrasyonlarının kombinasyonunu içeren sodyum aljinat filmleri, diğer deney gruplarına göre daha yüksek antioksidan etkiler gösterdiği görülmüştür. %0,004 RES + %1 THY içeren sodyum aljinat filmi, tüm uygulamalar arasında en yüksek antimikrobiyal ve antioksidan aktiviteyi ve en yüksek duyusal skorları sergilediği tespit edilmiştir. Bu bulgulara göre, RES ve THY kombinasyonunu içeren sodyum aljinat filmin, et ürünleri endüstrisinde doğal koruyucularla birlikte aktif bir ambalaj malzemesi olarak potansiyel uygulamasına dikkat çekilmiştir.

Khorsandi vd., 2019 ele alınan çalışmada, doğal antimikrobiyaller olan nisin, tarçın esansiyel yağı (CEO), etilendiamintetraasetat (EDTA) ve bunların kombinasyonlarının, vakumlu ambalaj altında 10 °C'de 42 gün süreyle saklanan emülsiyon tipi pişmiş kürlenmiş sosisin raf ömrü üzerindeki etkisini araştırmayı amaçlamıştır. Tüm numuneler depolamanın 1, 14, 28, 35 ve 42. günlerinde toplam sayım, LAB sayımı, pH, duyusal özellikler ve objektif renk açısından incelenmiş. Sonuçlara göre, nisin ve CEO uygulamalarının sosislerin raf ömrünü sırasıyla 14 ve 7 gün artırdığını, N + C ve N + E + C uygulamalarının ise raf ömrünü sırasıyla 7 ve 14 günden fazla uzatmada etkili olmadığını bildirmiştir. EDTA tek başına LAB ve toplam bakteri üremesini inhibe etmede etkisiz olmasına rağmen, E + C ve N + E ile muamele edilen sosislerin raf ömrü 14 günden (kontrol numuneleri) 35 güne uzatıldığı belirtilmiştir.

Pedro & Ferreira, 2006 ileri dönük raf ömrü belirleme stratejisinin araştırıldığı çalışmada endüstrileşmiş gıda ürünlerinin raf ömrünün belirlenmesi için yeni bir yaklaşım olan Çok Değişkenli Hızlandırılmış Raf Ömrü Testi (MASLT) uygulayarak konsantre domates ürünün raf ömrünün hesaplanması amaçlanmıştır. Hızlandırılmış raf ömrü testi gerçek raf ömrünün 28 ay olduğu tahmin edilen tek konsantre endüstriyel domates ürününe başarıyla uygulanmıştır.

Silva vd., 2014 tarafından yapılan çalışma, iki paketleme formatının (vakumlu paketleme ve sarma usulü paketleme) 4 ± 1 °C'de 90 günlük bir süre boyunca depolanan kan, kalp, böbrek ve keçi eti parçalarıyla hazırlanan pişmiş sosisin raf ömrü üzerindeki etkisini araştırmıştır. Depolama süresi ve ambalaj türü, pişmiş sosisin kimyasal (pH, nem, protein ve TBARS sayısı), fiziksel (kesme kuvveti) ve mikrobiyal (küf ve maya) parametrelerini önemli ölçüde etkilediği ifade edilmiştir. Çalışma vakumlu paketlemenin, pişmiş keçi kanı sucuğunun mikrobiyolojik ve kimyasal özelliklerini, sarma usulü ambalajlamaya (63 gün) kıyasla daha uzun bir süre (41 gün) koruduğu ve kaliteli bakım için ürünün buzdolabında depolanmasına uygun bir alternatif olabileceğini bildirmiştir.

Sonuç

Bu çalışmada sosis hakkında genel bilgiler verilmiş ve raf ömrünü etkileyen faktörler açıklanmıştır. Emülsiyon et ürünlerinin raf ömrü üzerine birçok faktör etki etmekle birlikte bu faktörlerin olumsuz etkileri önlenerek veya minimize edilerek ürünlerin raf ömrü uzatılabilir. Sosis türü et emülsiyonlarının raf ömrü doğrudan hammadde seçimi ve işlem prosesi ile ilgilidir. Bu aşamalarda raf ömrü belirleme çalışmaları ve raf ömrüne etki eden faktörlerin dikkatli belirlenmesi gerekmektedir. İşlenmiş et ürünleri arasında sosis bozulmaya karşı nispeten zayıf bir ürün olmasından dolayı proses ve hammadde seçimi ile ilgili gelişmelerin yanında yeni paketleme stratejileri üzerinde çalışılmaktadır. Gelişmiş paketleme stratejileri ile ürünlerin raf ömrünü uzatmaya yönelik doğaldan uzak katkı maddesi kullanımı minimize edilebilir ve insanların sağlıklı gıdalara erişimi sağlanır.

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ID: 623

An Overview On Fish Smoking, Nutritional Quality, Wood Biomass, And Their Effects On Health

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Abstract

Fishes are susceptible to spoilage which occurred as a results of different factors including high level of temperature, weather, acidity, processing and storage methods and during transportation. This lead to a significant loss during storage of fresh fish samples. Spoilage of fish can be achieved through subjecting the fresh samples to smoking. Cold or hot smoking method to improve shelf-life. The main purpose of this review focused differentiate fish smoking method and the effect of wood biomass on the smoked fish product. The method involved processing and smoking raw fresh fish species with different fuel-wood species to ascertain the quality of the smoked products based on the chemical composition of the smoked fish, composition of the woods biomass and the volatile compounds; both beneficial such as color, aromatic and flavor improvement as well as he harmful effect such as polycyclic aromatic hydrocarbons (HAPs) which poise a severe health effect. Pyrolysis generated from Wood smoke consist of complex mixture of liquids, solid particles and gases (aerosol) due to incomplete burning, pyrolysis or combustion of the wood biomass such as; charcoal, wood chunk, sawdust, wood pellets etc. at an elevated temperatures with reduced oxygen level. Besides the main product of pyrolysis which is 'carbon dioxide and water', wood biomass contain approximately more than 200 different organic compounds identified to induce mild, acute or severe chronic health effects when accumulated in humans body. The nutritional composition of smoked fish samples includes; crude fibre, water content, protein, ash content, amino acids, minerals, phenols and biogenic amines. All the locally available woods species that impart desired colour and flavor also contain minimal level of 0.2 – 5.0 milligram of PAHs per cubic meter of air i.e. (0.2 – 5.0 mg/M^3) are recommended as safe, while at high concentration of 10 and 15 milligrams of PAHs per cubic meter of air is generally considered unsafe and could pose a chronic health challenge.

Keywords: *Fish, Woody Biomass, Smoking, Composition, Health Effects*

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Heamatology and Serum Biochemistry of West African Dwarf Goats Fed Diets Containing Treated Rice Husk (RH) as a Replacement for Wheat Bran.

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Abstsract

The study was conducted to evaluate the effects of treated rice husk as a replacement for wheat bran on the haematology and serum biochemical parameters of West African Dwarf (WAD) goats. Twenty WAD goats were subjected to five dietary treatments in a completely randomized design with four goats per treatment. The treatments were 0% RH (T1), 25% RH (T2),50% RH (T3),75% RH (T4) and 100% RH (T5). The animals were fed at 5% of their body weight. Blood samples of 10 ml were collected at the end of the growth trial to analyze for haematology and biochemical components. Blood samples were taken before morning feeding via jugular vein puncture into two blood collection bottles. One containing an anticoagulant Disodium salt of ethylene diamine tetraacetic acid (EDTA) and the other with no anticoagulant from which serum was harvested for biochemical analysis. Packed Cell Volume (PCV), Haemoglobin (Hb), red blood cell (RBC) and total white Blood Cells (WBC) were determined. Mean Corpuscular volume (MCV), Mean Corpuscular haemoglobin (MCH) and Mean Corpuscular haemoglobin concentration (MCHC) was calculated from PCV, Hb and RBC. Serum biochemical parameters measured include glucose, total protein, albumin, blood urea nitrogen (BUN), aspartate aminotransferase (AST) and alanine aminotransferase (ALT) parameters were determined. Goat fed with diet T4 had better red blood cell, Pcv, hemoglobin, platelet, eosinophil and AST but high in cholesterol level. Goat on T2 had the highest Tp and better hemoglobin, Pcv, platelet lymphocytes, ALT and globulin content. The treated rice husk had positive impact on the blood parameters, the values are within the normal range for healthy goat. Hence, from this study, 25 – 50% treated rice husk replacement for wheat bran suggests suitable for better performance of WAD goats.

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Comparative Analysis Of Growth Performance And Economic Benefits Of West African Dwarf Goat Fed With Diets Incorporation Treated Rice Husk As A Substitute For Wheat Bran

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Abstsract

The study was conducted to find out effects of treated rice husk as a replacement for wheat bran supplement on the growth performance of West African Dwarf (WAD) goats. Twenty (20) WAD goats were subjected to five dietary treatments in a Completely Randomized Design (CRD) with four (4) animals per treatment and each serving as a replicate. The treatments are: 0% RH (T1), 25% RH (T2), 50% RH (T3), 75% RH (T4) and 100% RH (T5). The animals were fed 5% of their body weight. The result showed that T2 and T1 are relatively high in crude protein, low in crude fiber, moderate in crude fat and high in carbohydrate. They equally had the lowest values of ADF, ADL and NDF among the treatments. The total weight gain (TWG), average daily weight gain (ADWG), total daily feed intake (TDFI) and feed conversion ratio (FCR) were all significantly ($P < 0.05$) influenced by the dietary treatments. The goat, T1 had the highest TWG, ADWG and TDFI values among the goats. The goat fed 25% RH replacement level (T2) converted and utilized feed better and had better growth performance comparable to goats fed T1. In conclusion, at 25% level of treated rice husk as replacement of wheat bran gave better growth performance in the goats. The result demonstrated the qualitative benefits and financial returns of using treated rice husk to replace wheat bran diets for WAD goats. Thus, the use of treated rice husk up to 50% in the diet of WAD goats is recommended for appreciable growth performance and better economic benefits.

Key words: *Treated rice husk, West African Dwarf goat, weigh gain, feed conversion ratio, feed intake*

ID: 626

Enhancing Egg Production Efficiency in Small-Scale Open Shed Layer Farms: A Smart Data Monitoring Case Study with 950 Birds

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Abstract

Efficient management of egg production is essential for maximizing profitability in layer farming. Conventional monitoring methods often fail to detect early declines in productivity, leading to economic setbacks. This study investigates the use of a smart data-driven system to monitor egg production, identify low-yielding cages, and enhance farm management strategies.Utilizing Google Sheets and AppSheet, data from 950 layer hens housed in a cage system was systematically recorded and analyzed to detect production trends and abnormalities. A structured reporting system was developed to categorize underperforming cages on a weekly and monthly basis, with automated alerts for critical cases. Findings suggest that real-time data tracking enhances decision-making by allowing timely interventions such as feed optimization and health management.Additionally, the study highlights the impact of body weight on egg production, revealing that hens exceeding 2.0 kg tend to have lower productivity. Implementing strategies like controlled fasting and liver tonic supplementation contributed to improved egg yield.This research underscores the potential of technology-driven monitoring in enhancing farm efficiency, minimizing losses, and fostering sustainable poultry farming. Future advancements may include the integration of IoT-based automation for precise feed and environmental control.

Keywords: *Layer farming, egg production, smart monitoring, low production detection, poultry management, open shed farm.*

ID: 627

Assessing genetic variability, heritability and genetic advance for yield and yield components in common wheat

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Abstract

The present investigation was carried out to study some genetic diversity parameters i.e. the coefficient of variance, heritability and genetic advance for sixteen traits in common wheat. The trial included ten varieties used as phytogenetic material and parents of F1 individuals, whereas F2 individuals are obtained from self – fertilization of F1. The experimentation was conducted in randomized bloc design (RBD) with four replications. Measurements and data notations focused globally on direct and indirect yield components. Analysis of variance revealed significant differences among genotypes for all considered traits. The study showed wide amount of variability for all studied characters. We recorded high magnitude of both PCV and GCV for all the traits except of number of spikelets, spike length and number of grains in linear meter. Moreover, ECV had feeble values except of number of tillers and fertile tillers per plant and number of grains per plant. High values of broad sense heritability associated with high to medium magnitude of genetic advance as per cent of medium were recorded for all traits provided number of grains per plant and per linear meter.

Key words: *Common wheat, Morpho –phenologic traits, Genetic diversity, Heritability, Genetic gain.*

Introduction

On a worldwide scale, common wheat (Triticum aestivum L), among the cereals, is considered the most cultivated species feeding close to 40 % of the world's population. By their importance in Algerian menus and dishes, cereals in general and common wheat, in particular, occupy a significant part of the Utilized Agricultural Area, especially in the highlands where it has cohabited for a very long time and has become a profitable complement to sheep farming. Various methods and markers can be used to determine the genetic diversity of a species including morphological, biochemical, and molecular markers. Morphophysiological markers are widely used to study genetic diversity in plant species (Singh, G.P 1994; Mwirigi et al., 2009; Dhakar et al., 2012; Fikre et al., 2015; Seyoum and Sisay 2021). Determination of genetic variation in common wheat using morphological traits has been worldwide reported by many researchers (Gill & Brar 1977; Vavilov 1992; Williams et St Clair 1993; MacKey 1993; Zeven 1998; Firouzian et al., 2003; Lang et al., 2004; Garcia-Martinez et al., 2005; Sanchita et al., 2008; Salmi et Haddad 2015; Herison et al., 2018). Up till now, many studies dealt with botanic, morphophysiological and yield potential characterization of native common wheat varieties of Adrar region. However, little had been done in terms of genetic variability parameters studies of which it became a decisive factor for all reproduction program (Sanchita et al., 2008). Therefore, it is important to swipe widely in this direction for identifying the existing genetic capabilities of this local phytogenetic material in order to improve common wheat yield.

Materials and methods

The vegetal material for this trial comprises ten varieties used as parents of series of crossings, of which eight (08) are native to Adrar region, F1 individuals and F2 individuals. The trials were conducted in complete randomized bloc design with three (03) replications at local research station of National Institute of Agricultural Research. Sowing date is in December 29th 2023 distance between grains is 10 cm, while row are distanced every 18 cm. Adopted plot irrigation system is dripping and the frequency of irrigation is two to three times a week, depending on crop requirements and environmental conditions. The crop is conducted under standard technic itinerary and plot harvest was manually done at physiological maturity stage of the crop.

Studied traits:

The studied traits are as follows; tillers ability (Tal. P), Productive tillers (Tal. Ep), Plant height at maturity (H.T), number of grains per spike (Gr.E), number of pikelets per spike (Ept.T), number fertile spikelets per spike (Ept. Ft), spike length (L.E), spike density (D), Thousand grains weight (PMG), earliness to heading and yield (Yld).

Data analysis:

The collected data are subjected to analysis of variance where additive model suggested by Steel and Torrie (1980) is used

Yij = μ + gi + bj+ e(ij), where:
Yij = Observed value of genotype i on bloc j
μ = Trial mean
gi = Effect of genotype i
bj = Effect of bloc j
e(ij) = Residual of model
-The least significant difference (LSD) with p < 5 % was calculated following Steel and Torrie (1980)
LSD 5% = t 5, where:
-Phenotypic variance = $\delta_g^2 + \delta_e^2$ with δ_g^2 as genotypic variance
- Phenotypic, genotypic and environmental coefficient of variation was calculated according to Singh and Chaudhary (1985) formula.
GCV% =(δ_g^2 0.5 /$\bar{Y}$)*100 ; PCV% = (δ_P^2 0.5 /$\bar{Y}$)*100 ; ECV% =(δ_e^2 0.5 /$\bar{Y}$)*100
-$\bar{Y}$: is the studied trait mean.
For interpretation of parameters values we utilized Deshmukh et al.. (1986) scale.
-Broad sense heritability (h^2bs) was estimated as suggested by Falconer and McKay (1996)
h^2 (bs) = (δ_g^2 F2 – δ_g^2 F1) / δ_g^2 F2
For values interpretation, we employed the scale of Pramoda and Gangaprasad (2007).
-Genetic advance and genetic advance and GA as % of mean (GAM) were calculated according to Allard (1960):
GA: h^2 (bs) × $\sqrt{\sigma^2_p}$ × k. with
- $\sqrt{\sigma^2_p}$: Standard deviation of phenotypic variance of 2nd generation (F2)
K = Intensity of selection, the value of which is 2.06 when 5 percent of the individuals are selected from the population, as given by Lush. (1949).
GAM = (GA / $\bar{Y}$)*100.

Results and discussion:
Different variance sources, coefficient of variance and the least significant difference for all the sixteen characters are given in table 1. The analysis of variance revealed high significant differences between the genotypes means, resulting in significant effect of genotype for all considered characters (Table 1). Accordingly, the results showed substantial amount of genetic variability among genotypes studied, offering real possibilities of genotypes' improvement through hybridization and selection. Significant differences among genotypes for these traits were earlier mentioned for plant height (Sharma et al., 2020; Dragov et al., 2022), productivity tillering, spike length and number spikelets per spike (Dave et al., 2021; Chauhan et al., 2023; Kumawat et al., 2023), grains number per spike and grains weight per spike (Prasad et al., 2021; Ashebr Baye et al., (2020); Jalal A. Al-Tabbal et al., 2011)), thousand grains weight (Dragov et al., 2022; Sharma et al., 2020; Harshardhan et al., 2016). However, the mean square due to block was significant, only for two traits viz; plant height at maturity period and number of spikelets per spike.

Mean performance:
Regarding range as per cent of mean, it shows an important contrast of diversity among characters ranging from around 12.40 % for number of spikelets per spike to heading up to more than 88 % for mean rate of fertile tillers. High magnitude of diversity (> 20 %) was recorded for number of fertile tillers per plant, yield and number of grains per plant, spike length, tiller capacity, spike density, weight and number of spike grains. thousand grains weight and plant height, respectively. However, relatively low values were recorded for number of spikelets per spike. Indeed, high variability among this material for fourteen traits can constitute the base for a sound breeding program and select genotypes with desired traits for further improvement common wheat yield in such environmental conditions. Comparable findings have been in Harshwardhan et al., (2016); Prasad et al., (2021); Chauhan et al., (2023).
The main reference values (minimum, maximum and maximal) of the studied characters, Phenotypic, genotypic and environmental coefficient of variation, broad sense heritability, genetic gain and genetic advance as per cent of mean for sixteen traits are given in table 2.
A scale was established by Deshmukh et al (1968) regarding phenotypic and genotypic coefficient of variation (PCV, GCV) allow measuring the results extent. Accordingly, values were classified as high (> 20 %) moderate (10 to 20 %) and feeble (< 10 %). High to moderate magnitudes of GCV and PCV means that existing material has a wide range of polymorphisme indispensable for a promising program of selection.
However, low values of these parameters show that available variability rate is feeble within this material and the need to resume works of variability creation (recombination, gene mutation, chromosomal segregation…) followed by selection (Tiwari et al., 2012). Apart from the total number of tillers, fertile tillers and tillers to spike ratio, values of phenotypic coefficient of variation were slightly higher than genotypic coefficient of variation. Furthermore, environmental coefficient of variation values were generally feeble except of these traits, resulting in environment influence on the expression of characters was low for most of these studied characters.

Table 1: Analysis of variance for yield and its contributing traits in common wheat.

Srce /Trait	Tillers -Pte	Spikes/ Pte	% Spiks/tillers	Pte-Ht	T Spklts -Spike	Spike - Length	Dens	Wt-Spike Grains	Grains / Spiklt	Grains/ Spkls	Grains /Pte	Earliness to heading	TGW	Yield
Total	920.70	604.92	10 839.77	2 748.02	59.24	75.04	327.19	14.69	3 631.65	7.85	608 645.64	1 024,90	993.51	22 752.21
Variety	382.0 **	389.67 **	7 276.04 **	1 564.5 **	34.30 **	61.7**	256.77	12.16 **	1 256.6 **	3.69**	264 433.2 **	941,77 **	453.6 **	10 653.56 **
Rep	79.35	9.39	116.84	387.03 *	11.68 **	1.54	10.01	0.35	460.47	0.62	32 984.78	24,33	67.19	1 203.28
Error	459.35	205.87	3 446.89	796.45	13.26	11.76	60.41	2.18	1 914.60	3.54	311 227.63	83,13	472.73	10 895.36
LSD	0.57	1.87	7.66	3.68	0.47	0.45	1.01	0.19	5.71	5.71	72.74	1,84	2.83	13.61
CV %	23.57	25.15	28.28	6.98	3.07	6.54	7.12	12.73	13.10	12.26	26.38	2,10	11.61	25.76

N.B : (*) significant at 0.05 level. (**) significant at 0.01 level.

Table 2: Genetic variability parameters for yield and its contributing traits in wheat.

Trait./ Parameter	Tillers-Pte	Spikes/ Pte	% Spiks/tillers	Pte-Ht	Spklts - Spike	**Spike - Length**	**Dens**	Wt-Spike Grains	Grains/ Spike	Grains/ Spkls	Grains /Pte	Earliness to heading	TGW	Yield
Mean	19.18	12.03	75.16	74.45	22.65	10.10	21.39	2.31	64.66	2.94	386.37	76.68	38.15	64.35
Range	16.17 - 23.67	8.00-16.70	28.67-100.00	70.05 - 86.11	21.17 - 24.00	8.12-12.42	18.00 - 25.94	1.98-2.68	56.0-74.0	2.35-3.34	312.46-573.60	72.25-85.16	32.40 - 43.79	34.10-95.28
% range to Mean	39.11	80.47	84.43	21.58	12.51	42.59	37.12	30.40	27.84	33.51	67.59	16.84	29.86	95.08
Phenotyp variance	43,21	21,14	732.81	305.66	4,16	4.94	50.85	0,73	289,09	0,56	44380,21	68.01	104,91	1496,26
Genotyp variance	27,04	15,94	602.68	289.45	3,80	4.25	47.73	0,67	268,29	0,51	44185,09	63.47	92,80	1301,13
CVP %	41,98	38,24	67.79	23,48	9,28	11,67	31,82	39,11	26,58	25,33	**41,36**	10,76	29,99	48,55
CVG %	33,21	33,21	61.48	20,65	8,87	10,02	31,04	37,46	25,60	24,25	**41,26**	10,65	28,21	45,27
CVE %	55,61	23,77	28.57	11,19	2,73	5,99	7,02	11,24	7,13	7,33	**2,74**	1,47	10,19	17,53
H2 %	0,63	0,61	0.97	0.95	0,91	**0.73**	0.94	0,92	0,93	0,92	**0.99**	0.93	0,88	0,87
GA	8,31	7,78	13.88	9,41	5,71	5,16	10,85	11,76	9,81	9,45	**13,13**	6,27	9,93	12,42
GG %	53,08	64,71	32.39	12,63	25,96	51,49	48,44	539,49	15,33	320,67	**2,58**	8,18	29,08	15,59

Wolde et al., (2016), this is due to the genotype environment interaction. Abinasa et al., (2011), GCV and PCV values convergence shows a minor environmental effect on the expression of these traits and they are controlled by additive gene effects. However, wider difference between the values of GCV and PCV indicate non-additive genetic effects (Governed by dominance genes).

Among fourteen traits, eight possess high values (> 20 %) of phenotypic and genotypic coefficient of variation. It is about yield (48.55 and 45.27 %), number of tillers per plant (41.98 and 33.21 %), number of grains per plant (41.36 and 41.26 %), weight of spike grains (39.11 and 37.46 %), number of plant spikes (38.24 and 33.2 %), thousand grains weight (29.99 and 28.21 %), number of grains per spike (26.58 and 25.60 %), and number of grains per spikelet with 25.33 and 24.25 %, respectively. Additionally, two traits have moderate values (10 to 20 %), namely main spike length (11.67 and 10.02 %) and earliness to heading (10.76 and 10.65 %). Meanwhile, the magnitude of number of spikelets per spike was feeble (< 10 %). In terms of environmental coefficient of variation, its values were mostly feeble and exceptionally moderate to high. In fact, local environmental conditions have apparently significant effect on number of total and fertile plant tillers expression of which it stabilized during early advanced stages which coincides, to a large extent, with progressive resumption of high temperatures. Similar results were reported for the yield elements in early generations in Dragov et al., (2022). Moderate PCV and GCV values for the earliness to heading per main spike are in harmony with those obtained by Bendjama and Ramdani (2022). Feeble values of PCV and GCV for number of spikelets per spike are found (in late sown conditions) by Azimi et al., (2017). Indeed, high magnitude of GCV and PCV indicate existing real chance for selection of promising elite individuals for improvement of the traits.

Heritability is one of the crucial genetic variability parameters applied in breeding and selection for improving genotypes. According to Pramoda and Gangaprasad, (2007) scale, heritability values less than 0.4 (40 %) are considered feeble, average between 0.4 and 0.6 (40 to 60 %), high from 0.6 to 0.8 (60 to 80 %), and very high for

values above 0.8 (80 %). All traits were characterized by a high magnitude of heritability (> 0.80), except for spike length, which has high values of which number plant grains had the highest with 0.99 followed by plante height (0.95) , main spike density (0.94), number spike grains and earliness to heading (0.93), weight of grains per spikelet, weight of spike grains and earliness to heading (0.92), number of spikelets per spike (0.91), thousand weight grains (0.88), mean yield (0.83) and followed by spike length with 0.73. Nevertheless, Weak to moderate heritability values were obtained by Ahmad et al. (2023). According to Khan and Naqvi (2011), the direct selection on one single plant in early generations could be very effective for a character highly heritable. Present findings are comparable with Ali et al., (2008); Wolde et al., (2016), they also suggest that selection by the traits productivity tillers, plant height thousand grain weight can improve yield. Moreover, several researchers (Bhargava et al., 2003; Shukla et al., 2004) highlight the usage only of high heritability is not sufficient for selection and plant improvement programs, in early generation and must be associated with other genetic parameter especially genetic gain. Effectively, when high broad sense heritability values were supported by similar genetic advance magnitudes offer very solid real opportunities and consolidate such wheat improvement program.

According to Johnson et al., (1955) the estimates of genetic advance and genetic advance as percent of mean were classified as low < 10 %, moderate (10-20 %) and high (> 20). High to moderate genetic gain as percent of mean above 20 % associated with high values of heritability were reported for number of spikes per plant (64.71), number of tillers per plant (53.08 %), spike length (51.49 %), main spike density (48.44 %), thousand grains weight (29.08), number of spikelets per spike (25.92), number and weight of grains per spike. Moreover, Three traits possess mean GAM values i.e. yield (15.59 %),number of grains per spike (15.33 %) and plant height (12.63 %). However, two traits had weak values of genetic advance (<10%), namely number of grains per plant and earliness to heading. Moreover, these values have the same tendency as those of the above genetic parameters, except for heritability in the narrow sense. Furthermore, high heritability accompanied with low expected genetic advance signals influence of dominance genetic effects (Salman et al., 2014), which are suitable for heterosis breeding (Ilyas et al., 2019).

Within trial conditions, yield with both direct and indirect yield components traits, were characterized with high magnitude of genotypic parameters (genotypic and phenotypic coefficient of variation. heritability and genetic advance) and associated with relatively low environmental coefficient of variation except of spikes, tillers and tillers to spikes ration per plant. Consequently, direct selection during early generation based on phenotype is effective and would lead to a successful improving of these traits. For Mortez et al., (2018); Dragov et al., (2022), traits productivity, with high or medium genetic advance and high heritability, are controlled by several major genes with additive genetic action and effective selection is possible.

Conclusion

From the above results, it could be concluded that a high amount of genetic variability exists among these genotypes for almost the considered traits. The high magnitude of heritability of broad sense (> 60 %) was recorder for all traits except of density and length spike suggests a strong genetic effect for expression of the studied characters. Furthermore, substantial values of heritability associated with high to medium score of genetic gain as percent of mean (> 10 %) were noticed for nearly all studied traits, especially number of fertile tillers, plant height, number of spikelets per spike, thousand grains weight and yield grain. Consequently, all these mentioned traits expression are most likely governed by several additive genes, resulting in direct selection on individual plant in early generation lead potentially to a genetic improvement in common wheat grain yield.

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Assessing the Effect of Cassava Flour as a Binding Agent in Chicken Sausages

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Abstract

Meat products are widely consumed globally, offering a valuable opportunity to enhance health benefits through improved formulations. The purpose of the present study was to assess how varying levels of cassava flour (CF) incorporation (0%, 50%, 75%, and 100%) as a binding agent affects the nutritional composition, physicochemical properties, and sensory appeal of chicken sausages. This study was conducted in a completely randomized design (CRD) evaluating four (04) treatments (Control: 0%, CF50: 50%, CF75: 75%, and CF100: 100% CF substitution from the conventional binder mixture). Each treatment replicated three times. Cassava flour and all four treatments were analyzed for proximate composition and physicochemical properties. Sensory attributes were evaluated in a 6-point hedonic scale. One-way ANOVA was used to analyze proximate and physicochemical data and the sensory scores were separated using unpaired t-test. Results showed that the Control, CF50 and CF75 exhibited the optimal nutritional profile recommended for sausages. Increasing CF incorporation ($P<0.05$) changed pH to become more acidic. The water holding capacity, cohesiveness, gumminess, chewiness, external redness (a*), yellowness (b*) and internal lightness (L*), a* and b* values were similar ($P>0.05$) across all four treatments. Unlike the treatments CF75% and CF100%, incorporation of CF at 50% (CF50) produced sausages with favorable folding test scores, extract release volume (ERV), springiness, and external L* and in comparable with the control. Resilience was higher in CF50 and CF100 than the control. Total CF substitution (CF100) increased moisture retention but reduced cooking yield with increased cooking loss ($P<0.05$). Total CF substitution resulted the lowest hardness ($P<0.05$). The results of the sensory evaluation revealed that CF50 was the most preferred sausage treatment by the panelists ($P<0.05$). The present study concluded that CF when substituted by 50% in the conventional binder mixture optimally enhances the proximate profiles, physicochemical properties and sensory attributes of chicken sausages.

Key Words: *Cassava flour, Chicken sausage, Physicochemical properties, Sensory attributes, Texture.*

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Improvement of physicochemical and probiotic properties of frozen yoghurt by incorporating inulin and guar gum

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Abstract

Frozen yoghurt is considered as a healthy alternative for ice cream due to its probiotic properties. Inulin and guar gum are well known soluble dietary fibers used as gelling and stabilizing agents in food processing along with their prebiotic properties. However, not that much of investigations have been performed to evaluate their applications in frozen yogurts, particularly their combination effect on physicochemical, probiotic and sensory properties of frozen yogurts. Individual (2.7% inulin and 0.3% guar gum) and combined (2.7% inulin with 0.3% guar gum) effects of inulin and guar gum on pH, titratable acidity, melting rate, overrun, survival ability of probiotics and sensory attributes of frozen yoghurt were investigated in freezing (-18 0C) storage for a period of 21 days. During the frozen storage, a reduction of pH and an increment of acidity were noticed for all the tested samples. This was more in samples treated with both dietary fibers. The overrun rate was increased in the presence of inulin and guar gum where guar gum had a greater impact. In freezing storage, probiotic bacteria, *Bifidobacterium* (BB-12) and *Lactobacillus acidophilus* (LA-5) showed greater survivability in the presences of inulin and guar gum. This was more prominenet when both dietary fibers were added. Frozen yoghurt with combination of soluble dietary fiber (0.3 % guar gum and 2.7 % inulin) had the most appealing sensory characteristics. It is evident from this study that inulin can be combined with guar gum appropriately to enhance quality attributes of frozen yoghurt including probiotic properties.

Key Words: *Frozen yoghurt1, guar gum2, inulin3, physicochemical properties4, probiotics5*

Introductıon

Frozen yoghurt has combining characteristics of yoghurt (acidic taste) and ice cream (cooling effect) (Tamime and Robinson, 2007). This fermented diary product contains probiotic bacteria and thus is considered as a health beneficial alternative dairy product for ice cream. The environment of frozen yoghurt is not favorable for the existence of bacteria due to the fact that certain stress related environment factors such as pH, acidity, redox potential, freezing, oxygen, sugar concentration and osmotic effects, hydrogen peroxide, antagonistic impact of co-cultures, and mechanical shearing can cause damage to the bacterial cell (Mohammadi, 2011). So, it is a challenge to maintain the viability of bacteria in frozen conditions to get potential benefits.

Inulin is a soluble dietary fiber consisting of non-digestible carbohydrate called fructans that occurs mainly in chicory roots. The wider applicability of inulin in food industry is attributed to its unique functionalities like gel-forming ability, fat replacing ability, limited solubility in water, thermal stability in short food processing steps, hygroscopic and act as humectants, caloric value, low glycemic index, and prebiotic properties (Soiab *et al*., 2016). It has been revealed that the addition of soluble dietary fibers like inulin and guar gum had a protective effect on probiotic bacteria in frozen yoghurt (Isik *et al*., 2011). In addition, fiber incorporation modified and improved the texture, sensory characteristics and shelf-life of frozen yoghurt (Rezaei et al., 2014). They further reported that the addition of inulin remarkably improved the viability of Lactobacillus acidophilus and Bifidobacterium lactis. Working on different ice cream formulations, Aykan et al., (2008) found that inulin provided better flavor and textural properties of ice cream. Guar gum also possesses excellent gelling thickening and emulsifying properties and thus is a widely used food hydrocolloids in food industry (Gupta and Variyar 2018). Rezaei et al., (2011) reported that guar gum significantly affect the viscosity, overrun and melting rate of frozen yoghurt. Soluble dietary fibers like inulin, guar gum are universally agreed-upon prebiotics (Carlson, 2018). However, little is known on their impact on frozen yoghurt, particularly their combine effects on probiotic, physicochemical and sensory attributes in frozen yoghurt.

The present work focused to develop probiotic frozen yoghurt by incorporating inulin and guar gum aiming to determine the individual and combined effects of these soluble dietary fibers on physicochemical, probiotic and sensory attributes of frozen yoghurt.

Materials and methods

Frozen yoghurt preparation

Preparation of yoghurt

Standardized milk with 2.5 % fat was heated up to 70 ^{0}C and then sugar, gelatin, Highland full cream milk powder with 40 % fat was added and mixed until it dissolved well. The mixture was pasteurized at 95^{0}C for 5 minutes. After that, the mixture was cooled to 43^{0}C and inoculated with probiotic yoghurt culture. Then the prepared mixture was incubated at 43^{0}C for 3 hours until the pH become 5.

Preparation frozen yoghurt base mix

Frozen yoghurt base mix was prepared by mixing skim milk, cream, sugar, glucose syrup according to the recipe given by the Milco Pvt Limited. Then mix was heated to 90 ºC for 15 seconds for pasteurization.

Preparation of frozen yoghurt

Frozen yoghurt was prepared by mixing 70 % of yoghurt with 30 % of frozen yoghurt base mix and this mix was kept in refrigerator (at 7^{0}C) for 15 hours for aging. Laboratory home ice cream maker machine was used for the target overrun of 80 percent to prepare frozen yoghurt. The frozen yoghurt was then packed in cartons and hardened and then stored at -18 ^{0}C for 21 days.

Inulin and guar gum treatment

Inulin and guar gum were added to the frozen yoghurt base mix. Four treatments were tested as T1 (only 3% inulin), T2 (only 0.3% guar gum), T3 (2.7% inulin and 0.3 % guar gum) and control (with no dietary fibers).

Determination of overrun

A fixed volume of the aged pre-mix and its volume expansion after frozen yoghurt preparation (freezing step) were measured and the overrun was calculated using the below equation.

$$\text{Overrun} = \frac{\text{(Volume of frozen yoghurt - Volume of mix used)}}{\text{(Volume of mix used)}} \times 100$$

Determination of titratable acidity pH

The acidity level of yoghurt sample was measured as the amount of lactic acid according to AOAC, (2000) by titrating with 0.1% NaOH in the presence of two drops of phenolphthalein and pH was measured in melted frozen yoghurt samples according to AOAC method, (2000) by using a pH meter (PH850-DP portable pH meter).

Melting Rate

The method described by Muzammil *et al*., (2015) was employed to estimate the melting rate. Frozen yoghurt (50 g) was placed on a sieve (0.5 mm) set on top of a beaker at 25 °C. The melted frozen yoghurt was collected in the beaker. The time of first dripping was noted and the weight of melted frozen yoghurt and the weight of the residual sample were obtained after 30 min. The melting rate was calculated by dividing the melted sample over the time (g/min). Melting rate was calculated after one week of frozen storage.

Microbiological properties

Enumeration of probiotic LABs were carried out to measure the bacterial survivability during frozen storage. The plate count technique on selective media (MRS and M17) was used after inoculation (starting level, 0 day) and after 21 days of frozen storage at -18 ^{0}C. Each sample was prepared following the methods provided by the International Dairy Federation (IDF, 2003). Enumeration of *Streptococcus* species was done on M17 agar by aerobic incubation at 37 ^{0}C for 48-72 h. Enumeration of *Bacillus* species was carried out on MRS agar after being adjusted to pH 5.4 by anaerobic incubation at 37 ^{0}C for 48-72 h as described by Almeida *et al.*, (2008).

Sensory properties

The sensory characteristics were measured using 15 trained and non-trained panelists for day 21 samples. The scores were allocated according to 5-point hedonic scale and the acidity, smoothness, yoghurt flavor, sweetness, freshness of samples was evaluated. Samples were ranked according to the overall acceptability.

Statistical analysis

Data were analyzed using SPSS univariate, Duncan's mean separation and LSD multiple comparison. Graphs were illustrated using Microsoft Excel 2010. The sensory evaluation data were analyzed in non-parametric Freidman test using SPSS statistics 26.0 version.

Results and discussion

pH and Titratable acidity

The change of titratable acidity and pH of frozen yoghurt samples are shown in Table 1. The acidity of all the tested samples was increased during the storage time while reducing the pH. The drop of pH is comparatively more prominent in samples treated only with inulin whereas the development of acidity (0.10) appeared to be the highest in sample treated with both dietary fibers at the end of storage time. Control sample showed the lowest development of acidity during frozen storage (0.083). According to the literature (Żbikowska et al., 2020, Rezaei et al., 2014, Aryana et al., 2007), the acidity is increased during the storage due to the lactic acid production by lactic acid bacteria utilizing prebiotics and thus high acid production shown in combined dietary fiber treated sample could imply that the use of both inulin and guar gum support the greater frozen storage survival and growth of probiotic bacteria. By performing the preliminary consumer preference and acceptance tests, some studies have

reported that consumers are most preferred the frozen yoghurts with pH range 4.3 to 5.3 and even in some cases 4.0 to 5.7 (Ionna *et al*., 1990, Isik *et al*., 2011). The pH range of the all the frozen yoghurt samples tested was in the consumer acceptable range.

Table 01:. pH and titratable acidity of frozen yoghurt incorporated with inulin and guar gum during frozen storage

	pH	
	Day 0	Day 21
Control	4.950±0.01a	4.817±0.005b (0.133
T1	4.970±0.01a	4.787±0.015b (0.183
T2	4.973±0.005a	4.830±0.01b (0.143
T3	4.980±0.01a	4.830±0.02b (0.150
	Titratable Acidity	
Control	0.677±0.005a	0.760±0.01b (0.0830
T1	0.677±0.005a	0.770±0.01b (0.093
T2	0.673±0.005a	0.767±0.005b (0.94
T3	0.667±0.005a	0.767±0.005b (0.10

Means in the same raw indicated by different letters are significantly different ($P < 0.05$)

Overrun and melting rate

The addition of inulin and guar gum increased the overrun of the frozen yoghurt where guar gum had much greater impact than inulin and when inulin was combined with guar gum the resulting overrun was higher than their individual impact (Table 2). The higher the overrun the lower the melting rate in frozen yoghurt. According to Sofjan and Hartel, (2004) higher overrun made ice creams with smaller initial air cell, due to the higher shear stresses during processing. Further they mentioned that lower overruns produced harder ice cream than that of higher overrun (120%) but they melted rapidly. It has been found the rate of overrun is increased in the presence of inulin in frozen yoghurt (Rezaei et al., 2014). Several studies observed the reduction of melting rate of frozen yoghurts and ice cream due to the added inulin (Xavier and Ramana 2021, Isik et al., 2011). Guar gum is commonly used in stabilizing ice cream and as a thickener in food applications due to its extremely high viscosity enhancement even at a very low concentration (≤1% w/v) in aqueous solutions (Gupta and Variyar 2018, Jagdish et al., 2015). Rezaei et al., (2011) also observed that gums like guar gum significantly alters the viscosity, melting rate and rate of overrun in frozen yoghurt.

Table 02: Melting rate and overrun in the inulin and guar gum added frozen yoghurt

	Melting rate (g/min)	**Overrun %**
Control	0.7300±0.010a	54.0967±1.035c
Treatment 1	0.7044±0.015b	56.0100±0.555b
Treatment 2	0.5156±0.005c	79.1733±0.259a
Treatment 3	0.5056±0.005c	79.2633±1.223a

Mean values with different letters shown in columns are significantly different ($P < 0.05$).As reported by Tamime and Robinson, (2007) overrun of frozen yoghurt should be in between the range of 50-60 % to consider as soft frozen yoghurt and 70-80 % overrun for hard frozen yoghurt. Each frozen yoghurt samples tested in this study falls within the above ranges in which control and Treatment 1 ranged 50-60 % while Treatment 2 and 3 ranged 70-80 %. According to Muse and Hartel, (2004) factors affecting on the melting rate of ice cream include destabilization of fat, the size of ice crystal and the consistency coefficient of the mix. As Xavier and Raman, (2021) reported, high water absorption capacity of soluble dietary fibers could cause a significant increase in melting time of ice cream. They further mentioned that soluble fibers enhanced the serum concentration of ice cream mixture resulting in increased viscosity and reduced melting rate. Dwórznicka et al., (2022) reported that the properties of ice cream produced with combination of soluble dietary fibers, especially, guar gum with another dietary fiber showed positive results in shortening of melting time. This claim is further confirmed from the results we observed in present study. The decreased meltdown rate offers ice cream with better melting resistance.

Probiotic bacteria count

Table 03: Colony forming units of probiotic bacteria (Lactobacillus acidophilus, Bifidobacterium, Streptococcus thermophilus) in inulin and guar gum added frozen yoghurt

Treatment	N	Day 0 1011 (cfu/g)	Day 21 108 (cfu/g)
Control	3	6.00 ±1.00a	09.00±1.00c
Treatment 1	3	7.00 ±1.00a	60.00±10.00b
Treatment 2	3	6.33 ±0.57a	66.66±5.77b
Treatment 3	3	6.66 ±1.52a	390.00±10.00a

Means in the same column indicated by different letters are significantly different ($p < 0.05$).

Probiotic counts in all freshly prepared samples were not significantly different (Table 03). However, from all the tested samples a significant reduction of probiotic counts was observed at the end of the storage time but to a different extent. Decomposition of bacteria counts could attribute to cold shock and osmotic pressure caused by freezing (Magariños et al., 2007). Rezaei et al., (2014) have also reported the reduction of number of lactic acid bacteria during cool storage. The highest remaining count after the 21 days of frozen storage was exhibited from treatment 3 (0.3 % guar gum+2.7 % inulin) followed by treatment 1 and 2 and the lowest from control sample. These results suggest that the inulin and guar gum significantly improve the survivability of probiotic bacteria in unfavorable environment existed in frozen storage and this is more in samples treated with both inulin and guar gum indicating that combine effect of inulin and guar gum provides a more favorable environment for probiotic bacteria than their individual counterparts. Inulin is one of the most commonly used prebiotics in dairy products (Żbikowska et al., 2020, Soukoulis et al., 2009). The decline rate of probiotic bacteria counts in inulin-containing frozen yoghurt samples showed lesser than the control sample (Rezaei et al., 2014, Isik et al., 2011). The recommended dose to receive the health benefits of the probiotic organisms, especially Bifidobacterium should be 106 cfu/g (FAO-WHO, 2003). In the present study, the total colony count of probiotic bacteria (Bifidobacterium and Lactobacillus acidophilus) remained after the frozen storage was higher than the above recommended value, particularly when both inulin and guar gum were added together. This is confirmed by the finding of Waitzberg et al., (2012) who found positive results when using prebiotic inulin- hydrolyzed guar gum mixture on the composition of intestinal microbiota. Further, they have mentioned that the combination of inulin and guar gum had an additional protective effect on gut microbiota by decreasing the number of pathological bacteria of the Clostridium genera.

Sensory analysis

Sensory characteristics, the taste, aroma, texture or color are the key quality attributes that play a crucial impact on consumer attraction. Keeping the appropriate sensory characteristics during the storage of frozen yoghurt is one of the most important things need to be maintained. Figure 1 , shows the results of Friedman's test analysis done for the different sensory attributes of 21 days stored samples. Acidity, smoothness, yoghurt flavor and sweetness were not significantly different among all the tested samples at the end of freezing storage time (21 days at -18 °C). But combination of inulin with guar gum had slightly higher sensory values of smoothness, sweetness and freshness than other treatments. The lowest sensory values of acidity and sweetness were noticed from control sample.

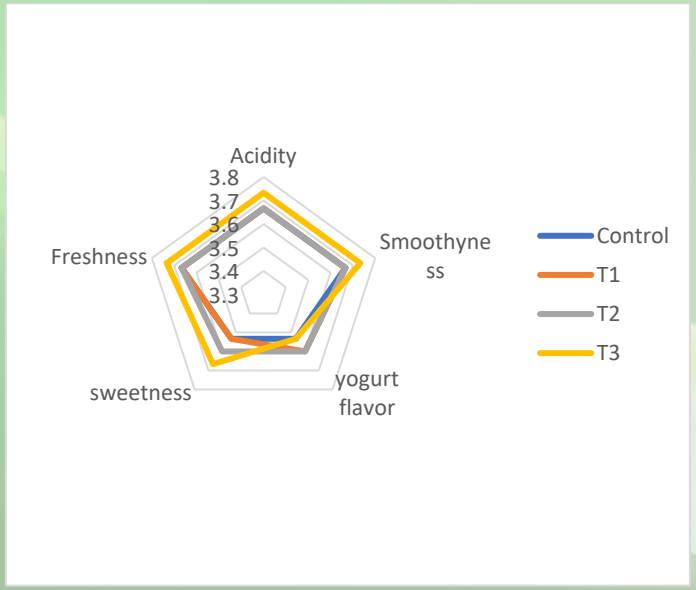


Figure 01: Sensory properties of frozen yoghurt prepared with inulin and guar gum at the end of day 21.

Dietary fiber can provide a wide range of functionalities to food especially in dairy products. They can modify and improve the texture and sensory characteristics of foods through their water-binding and gel-forming ability, fat mimetic, anti-sticking, anticlumping, texturizing and thickening ability (Soukoulis et al., 2009, Yangilar, 2013, Rezaei et al., 2014). According to Isik et al., (2011), except for the foamy melting attribute, adding inulin makes no significant difference in any of the sensory characteristics between tested frozen yoghurt samples. Akin, (2005) reported that inulin addition in (1% to 2%) had no impact on sensory attributes of frozen yoghurt. In contrast, Rezaei et al., (2014) mentioned that inulin improved the flavor, texture and total acceptance of frozen yoghurt. Guar gum is added to various dairy products due to its number of important functional properties (Gupta and Variyar, 2018). It has been reported that 0.2% of guar gum is sufficient to enhance the overall consumer acceptability of ice cream (Jagdish et al., 2015). The present study revealed that the inulin (2.7%) and guar gum (0.3%) together improved the yoghurt sweetness, freshness and smoothness during frozen storage showing combination effect has more impact on sensory attributes than individual effect of inulin and guar gum.

Conclusion

Inulin and guar gum significantly and positively alter probiotic, physicochemical and consumer acceptable qualities of frozen yoghurt where the combination effect of inulin and guar gum has more impact on the above properties of frozen yoghurt than their individual counterparts. It can be concluded that the soluble dietary fiber, inulin and guar gum in combination can be used as prebiotics in frozen yoghurts to improve probiotic bacteria viability with high consumer acceptable organoleptic properties. Further studies are required to optimize the combination effect of inulin and guar gum in a view of producing more heath beneficial and consumer acceptable frozen yoghurt.

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ID: 630

Chemical Constituents Of Propolis Relevant To Its Use In Polymeric Formulations

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Abstract

Propolis, a resinous substance collected by bees from plant sources, has gained increasing attention in pharmaceutical chemistry due to its rich composition of bioactive compounds and versatile therapeutic properties. This review aims to explore the key chemical constituents of propolis that contribute to its effectiveness in polymer-based drug delivery systems. Major compounds such as flavonoids, phenolic acids, terpenoids, and aromatic esters are identified as pivotal in providing antimicrobial, antioxidant, anti-inflammatory, and wound-healing activities. Advanced analytical techniques including HPLC, FTIR, and LC-MS have facilitated the precise profiling of these constituents in various types of propolis, with Brazilian red propolis being particularly well-characterized. The incorporation of propolis into natural and synthetic polymeric matrices—such as hydrogels, mucoadhesive gels, chitosanates, and collagen-based films—has shown enhanced physicochemical stability, controlled drug release profiles, and improved biocompatibility. Notably, polymeric systems loaded with propolis demonstrated significant antibacterial activity, thermostability, and antioxidant capacity, affirming their potential in topical and oral pharmaceutical applications. This review evaluates the structural and functional implications of propolis constituents in polymeric formulations, providing a basis for further development of bioactive delivery systems. Ultimately, this study reviews several chemical constituents of polymeric propolis and their relevance to pharmaceutical formulation and function.

Key Words: *propolis, polymer, chemical constituent, natural source*

Polimerik Formülasyonlarda Kullanımına Ilişkin Propolisin Kimyasal Bileşenleri

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Özet

Arıların bitkisel kaynaklardan topladığı reçinemsi bir madde olan propolis, içerdiği zengin biyolojik olarak aktif bileşenler ve çok yönlü terapötik özellikleri nedeniyle farmasötik kimya alanında giderek daha fazla ilgi görmektedir. Propolisin içeriğinde yer alan flavonoidler, fenolik asitler, terpenoidler ve aromatik esterler gibi başlıca bileşikler; antimikrobiyal, antioksidan, antienflamatuar ve yara iyileştirici aktiviteleriyle ön plana çıkmaktadır. HPLC, FTIR ve LC-MS gibi ileri düzey analitik teknikler, özellikle Brezilya kırmızı propolisi olmak üzere çeşitli propolis türlerinde bu bileşenlerin hassas şekilde tanımlanmasına olanak sağlamıştır. Propolisin polimer bazlı ilaç taşıyıcı sistemlerdeki etkinliğine katkı sağlayan temel kimyasal bileşenlerini inceleyen çok sayıda çalışma mevcuttur. Propolisin doğal ve sentetik polimerik matrislere—hidrojeller, mukoadeziv jeller, kitosanatlar ve kolajen bazlı filmler gibi—entegrasyonu; fizikokimyasal stabiliteyi, kontrollü ilaç salım profillerini ve biyouyumluluğu artırmıştır. Propolis yüklü polimerik sistemlerin belirgin antimikrobiyal aktivite, termal stabilite ve antioksidan kapasite sergilediği gözlemlenmiş, bu da onları topikal ve oral farmasötik uygulamalar için güçlü adaylar haline getirmiştir. Bu derleme, propolis bileşenlerinin polimerik formülasyonlardaki yapısal ve fonksiyonel rollerini değerlendirerek polimerik propolisin çeşitli kimyasal bileşenlerini ve bunların farmasötik formülasyon açısından önemini inceleyip, biyolojik olarak aktif taşıyıcı sistemlerin geliştirilmesi için bir temel sunmaktadır.

Anahtar Kelimeler: *propolis, polimer, kimyasal bileşen, doğal kaynak*

ID: 631

Characterisation and Antioxidant Activity of Pectin from Sweet Potato Starch Extraction Residues

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Abstract

There is limited information on the recovery of pectin from sweet potato starch extraction residues. Besides, the extraction parameters and raw material source affect the preferred functional properties of the pectin. Hence, the current study investigated the effect of temperature and extractant concentration on pectin yield, purity and characteristics. It was found that temperature and extractant concentration played an important role in influencing pectin yield and molecular weight (MW), and its side chain composition was mainly rhamnose, arabinose and galactose. In addition, it is worth noting that galactose was the main neutral sugar of the extracted pectin side chain, similar to citrus and apple pectin. The maximum pectin yield was realised with 90ºC and 0.05% SHMP, the pectin yield was 14%, and its degree of methoxylation and MW values were approximately 12% and 645kDa. The pectin possessed good antioxidant and ferrous ion chelation activity.

Pectin was extracted and further characterised from sweet potato starch pomace with combined sodium hydroxide and sodium hexametaphosphate. The chemical composition, molecular weight, degree of methoxylation, neutral sugar composition antioxidant capacity and iron chelation capacity were assessed. The extracted pectin had up to 72% galacturonic acid content, 14%yield, and 12% DM, which was confirmed by FTIR analysis. The pectin exhibited strong antioxidant capacity and high iron chelation activity.

Keywords: *Pectin extraction; characterization; FTIR; chelation; Antioxidant*

ID: 632

Effect of Seed Priming Using Botanical Extracts on Germination of Okra (*Abelmoschus esculentus Var. Nancy)*

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Abstracts

The germination in okra is poor due to its tough seed coats, undeveloped embryos, and adverse conditions which seems problematic in its cultivation. Seed priming is one of the best way to induce the seed germination and crop vigor in okra. Therefore, an experiment was conducted to evaluate the effects of seed priming on okra seeds using botanical extracts at College of Natural Resource Management, Bardibas, Mahottari, Nepal. Nancy (F_1) variety was taken to conduct the research using 6 different treatments i.e.(control, distilled water, 4% cow urine solution, 4% Moringa leaf extract solution, 4% Tulsi leaf extract solution and 4% Siris leaf extract solution) and 3 replications in Complete Randomized Design (CRD). The seeds were soaked for 15 hours in priming solution and dried at room temperature for 2 hours before sowing. The germination diversity parameter was recorded and analyzed through Genstat ver.2015. The results revealed that 4% Tulsi leaf extract solution shown highest germination % (83.33%), speed of germination (27.73 seeds/day), seedling length (23.63cm), dry weight (0.2990), seed vigor index 1 (1968cm) and seed vigor index 2 (24.84) followed by 4% Siris leaf extract solution with 75.56% germination, 23.48 seeds/day speed of germination, 22.51 cm length of seedling, dry weight of 0.2147, seed vigor index 1 (1705 cm) and seed vigor index 2 (16.24) as compared to control with (45.55 %) seed germination, (12.76 cm) seedling length, (0.088) dry seedling weight, SVI1 with 579 cm and SVI2 with (4.02). Seed priming with Tulsi leaf extract along with moringa and siris found to effective in improving seed germination and vigor in okra. So, this experiment should be conducted in farmer's field and larger plot for validation.

Keywords: *Botanical, extracts, germination, moringa, okra, seed-priming, siris, tulsi, urine.*

ID: 633

Nutrition-Focused Evaluation of Tomato Lines for Sustainable Food Systems In Bangladesh

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Abstract

An evaluation trial was conducted on new tomato lines to study their yield, pest and disease resistance, quality attributes, and potential nutritional contributions at the experimental field of the Olericulture Division, Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur, during the winter season of 2023-24. Fruit yield varied significantly, ranging from 15.7 to 150.4 t/ha. The highest yields were obtained from the lines SLA 035 (150.40 t/ha), SLA 031 (126.54 t/ha), SLA 039 (107.23 t/ha), SLA 040 (111.33 t/ha), SLA 044 (98.91 t/ha), SLA 041 (87.40 t/ha), SLA 045 (86.16 t/ha), SLA 030 (84.70 t/ha), and SLA 043 (80.79 t/ha). These lines also demonstrated promising traits in terms of earliness, quantitative and qualitative characteristics, as well as resistance to late blight, TYLCV, bacterial wilt, leaf miner, and fruit borer infestations. Given Bangladesh's high prevalence of micronutrient deficiencies, particularly vitamin A and C, tomatoes serve as an important dietary source of antioxidants, vitamins, and minerals. The selected high-yielding and disease-resistant lines could enhance tomato production, ensuring better availability and affordability of nutrient-rich vegetables for the population. Further evaluation of their nutritional profiles, including lycopene, β-carotene, and ascorbic acid content, would be beneficial to confirm their potential in addressing malnutrition. These nine promising lines—SLA 035, SLA 031, SLA 039, SLA 040, SLA 044, SLA 041, SLA 045, SLA 030, and SLA 043—are recommended for further confirmation and potential release to improve both food security and nutritional outcomes in Bangladesh.

ID: 634

Advancing Tomato Hybrid Development: Yield Evaluation of Winter-Grown Hybrids in Bangladesh

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Abstract

A field trial was conducted at the Olericulture Division of HRC, BARI, Gazipur during the 2023-24 winter season to evaluate eight tomato hybrids for yield performance, pest and disease resistance, and quality parameters. The study revealed significant variation in key traits including fruits per plant (36.0-155.0), individual fruit weight (14.5-90.0g), yield (up to 111.38 t/ha), fruit dimensions, TSS content, and resistance to TYLCV and leaf-sucking pests. The hybrids demonstrated maturity periods of 99-104 days to first harvest. Three hybrids showed exceptional performance: F_1 4601 (111.38 t/ha), F_1 1501 (103.85 t/ha), and F_1 1903 (100.22 t/ha) under Gazipur conditions. Based on comprehensive evaluation of yield attributes and resistance characteristics, F_1 4601 and F_1 1501 emerged as the most promising candidates for commercial release as new hybrid varieties. This study highlights the critical role of hybrid tomato development in Bangladesh's agricultural sector, where improved varieties can address key challenges of productivity constraints and pest pressures. The selected hybrids demonstrate the potential to significantly enhance tomato production efficiency, offering farmers higher yields with reduced input requirements. Their development aligns with national priorities to boost horticultural productivity through advanced breeding techniques, contributing to food security and economic growth in Bangladesh's rapidly evolving agricultural landscape. The successful performance of these hybrids underscores the importance of continued investment in hybrid vegetable breeding programs to meet the country's growing demand for high-quality, disease-resistant tomato varieties.

ID: 635

Productivity And Nutritional Potential Of Sweet Pepper Varieties In Bangladesh

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Abstract

An experiment was conducted at the central experimental farm of the Olericulture Division, HRC, BARI, Gazipur from October 2023 to April 2024 to evaluate four sweet pepper lines against the check variety BARI Mistimorich-2. The line CA 0043A showed the earliest harvestability (64.05 days), while CA 0046 produced the highest number of fruits/plant (9.43) and largest average fruit weight (106.32g). Yield performance ranged from 24.21 to 29.07 t/ha, with CA 0043A demonstrating superior productivity (29.07 t/ha). The selected line CA 0043A, characterized by red bell-shaped fruits, showed minimal pest infestation under protected cultivation and has been recommended for release as BARI Mistimorich-3. This development holds particular significance for Bangladesh's nutritional security, as sweet peppers are rich sources of vitamin C (ascorbic acid), vitamin A precursors (β-carotene), and antioxidants - critical nutrients for combating widespread micronutrient deficiencies. The high-yielding CA 0043A line presents opportunities to enhance year-round availability of nutrient-dense vegetables, particularly important for vulnerable populations. Its early maturity and protected cultivation compatibility address both productivity challenges and pesticide residue concerns. The release of this improved variety aligns with national efforts to diversify vegetable production and improve dietary quality, contributing directly to SDG targets on food security and nutrition. Further nutritional profiling of this line should be conducted to quantify its specific contributions to addressing vitamin deficiencies prevalent in Bangladesh.

ID: 636

Accelerating Sweet Pepper Improvement: Inbred Line Development For Bangladeshi Varieties

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Abstract

An experiment was conducted during the 2023-24 winter season at the Olericulture Division, HRC, BARI to evaluate fourteen sweet pepper lines (CA0008-CA0020) against the check variety BARI Mistimorich-1, aiming to develop superior inbred lines for hybridization and quality varietal development. Significant variations were observed in all evaluated parameters, particularly in yield-related traits. The line CA0014 demonstrated exceptional earliness, requiring only 39.11 days to 50% flowering, while CA0020 produced marketable fruits earliest (57.70 days). CA0012 showed superior fruit productivity (17.44 fruits/plant), and CA0014 recorded the highest yield (11.90 kg/plot, equivalent to 42.50 t/ha). Based on comprehensive evaluation of earliness, fruit size, and yield performance, six promising lines (CA0011, CA0012, CA0014, CA0015, CA0016, and CA0018) were selected for advancement in hybridization programs and potential varietal release. This study contributes significantly to Bangladesh's sweet pepper improvement program by identifying high-performing inbred lines with desirable horticultural traits. The selected materials possess optimal characteristics for developing F_1 hybrids with enhanced productivity and quality attributes, addressing the growing demand for improved sweet pepper varieties in Bangladesh. The findings underscore the importance of systematic line evaluation in quality varietal development, which is crucial for meeting both farmer needs and consumer preferences in the domestic market. These advanced lines will form the genetic foundation for future breeding efforts aimed at developing superior sweet pepper varieties with improved yield potential, adaptability, and quality traits suitable for Bangladeshi agro-climatic conditions.

ID: 638

Effect of Moringa Leaf Lxtract (MLE) on Sprouting and Growth Responses of Stem Cuttings of China rose (*hibiscus rosa- sinensis l.)*

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Abstract

The China rose, also known as *Hibiscus rosa-sinensis*, is a tropical flowering plant renowned for its large, vibrant blossoms. It is native to East Asia and thrives in warm climates. The propagation of China rose (*Hibiscus rosa-sinensis*) face several challenges, such as Rooting difficulty, inconsistent growth so that the present study investigates the effects of Moringa Leaf Extract (MLE) on the sprouting and growth responses of stem cuttings of Hibiscus rosa-sinensis L. (China Rose). Healthy, mature, and disease-free moringa leaves were carefully collected from near the Faculty of Crop Production Sindh Agriculture University, Tandojam. The leaves were washed under running water and then kept in a freezer for a day. Subsequently, the frozen leaves were crushed to extract juice with a locally made mortar and pestle. Moringa leaf extract was made with different concentrations, after which it was passed through a sieve before applying it to the cutting. The cuttings were 9 inches long and soaked for 5 hours in four different concentrations of MLE (10%, 20%, 30%, and 40%) they were planted in plastic bags filled with canal silt. the research utilized a Completely Randomized Design and assessed various growth parameters including sprouting percentage (%), number of sprouts per cutting, rooting percentage (%) fresh root biomass (g), dry biomass of roots (mg), fresh shoot biomass (g), Dry biomass of shoot (mg), Root Collar Diameter (mm). Results revealed that while sprouting percentages reached 100% at all MLE concentrations, the number of sprouts per cutting peaked at 10% MLE, indicating enhanced growth responses at this concentration. Furthermore, MLE significantly improved rooting percentages and biomass metrics, with optimal results observed at 10% concentration, while higher concentrations led to diminished effectiveness. The study concludes that MLE serves as a potent growth promoter for the propagation of China Rose, highlighting its potential in horticultural practices.

Key Words: Moringa leaf Extract (MLE)1, Sprouting2, Growth3, China rose3, Development5

Introduction

(Hibiscus rosa-sinensis L.), commonly known as the China Rose, is a species of flowering plant in the Malvaceae family.It is native to East Asia, but due to its aesthetic beauty, the plant has spread widely across the globe, particularly in tropical and subtropical regions(Magdalita et al., 2022). Revered for its striking, large flowers, Hibiscus rosa-sinensis has become a popular ornamental plant, cultivated for both aesthetic and medicinal purposes. The plant's cultural significance, ease of cultivation, and versatile applications make it an important species in both horticultural and traditional medicinal fields(Kosenkoet al., 2020).The China Rose is a shrub that typically grows between 1.5 and 2 meters in height, although some varieties can grow taller under optimal conditions. Its leaves are dark green, glossy, and elliptical, often with serrated edges. The flowers are the most striking feature of the plant, usually large, trumpet-shaped, and ranging in color from vibrant reds, pinks, and yellows to whites and purples. The flower has five petals and typically measures 4-5 inches in diameter. It has a prominent central stamen structure, adding to its ornamental appeal (Armitage, 2008).The plant blooms profusely throughout the year, particularly in warm climates. Hibiscus rosa-sinensis is not only important in ornamental gardening, but it also has ecological benefits. The plant attracts pollinators like bees and butterflies, playing a key role in supporting biodiversity in the ecosystems where it is found. In many tropical and subtropical regions, Hibiscus rosa-sinensis is often used in landscaping, parks, gardens, and as hedging plants due to its vibrant colors and hardy nature.In addition, it holds cultural significance in various parts of the world. In Hindu culture (Roy, 2013).

Propagation of *Hibiscus rosa-sinensis* is primarily carried out through stem cuttings, which is a common method for reproducing desirable traits such as flower color, size, and growth habits. However, the success of stem cutting propagation can be influenced by various factors, including hormonal treatments, environmental conditions, and nutrient availability Izadi et al., 2014).

Moringa oleifera, often referred to as the "miracle tree," has gained considerable attention for its rich nutritional content and medicinal properties. Moringa leaf extract (MLE), which is derived from the leaves of this plant, has demonstrated various beneficial effects in agricultural practices, including enhancing plant growth, improving root development, and promoting faster sprouting.(Mashamaite et al., 2022). Moringa is rich in growth hormones, vitamins, minerals, and antioxidants, which can potentially influence the physiological processes of plant cuttings and improve their success rate during propagation.The application of Moringa leaf extract (MLE) to stem cuttings of ornamental plants like *Hibiscus rosa-sinensis* could represent a valuable method for improving the rooting and growth performance of cuttings.

Materials and Methods

Study location

The experiment was carried out at the Nursery of the Department of Horticulture, Sindh Agriculture University (SAU), Tando Jam, within the agro-ecological environment of Tandojam, Sindh, Pakistan, during November-December 2024. The major aim of this research was to evaluate the effect of moringa leaf extract (MLE) on sprouting and growth responses of stem cuttings of china rose (hibiscus rosa- sinensis l.).

Preparation of Moringa Leaf Extract

Healthy, mature, and disease-free moringa leaves were carefully collected from near the Faculty of Crop Protection Sindh Agriculture University, Tandojam. The leaves were washed under running water and then kept in a freezer for a day. Subsequently, the frozen leaves were crushed to extract juice with a locally made mortar and pestle. Moringa leaf extract was made with different concentrations, after which it was passed through a sieve before applying it to the cuttings. Twenty cuttings of china rose were dipped with varying concentrations of moringa leaf extract (MLE), as per the treatments: (M_1= Control-no MLE), M_2 = 10% of MLE , M_3 = 20% of MLE , M_4 = 30% of MLE , M_5 = 40% of MLE. For each treatment, the cuttngs were immersed in the specific MLE solution for a period of 12 hours.

Results and Discussion

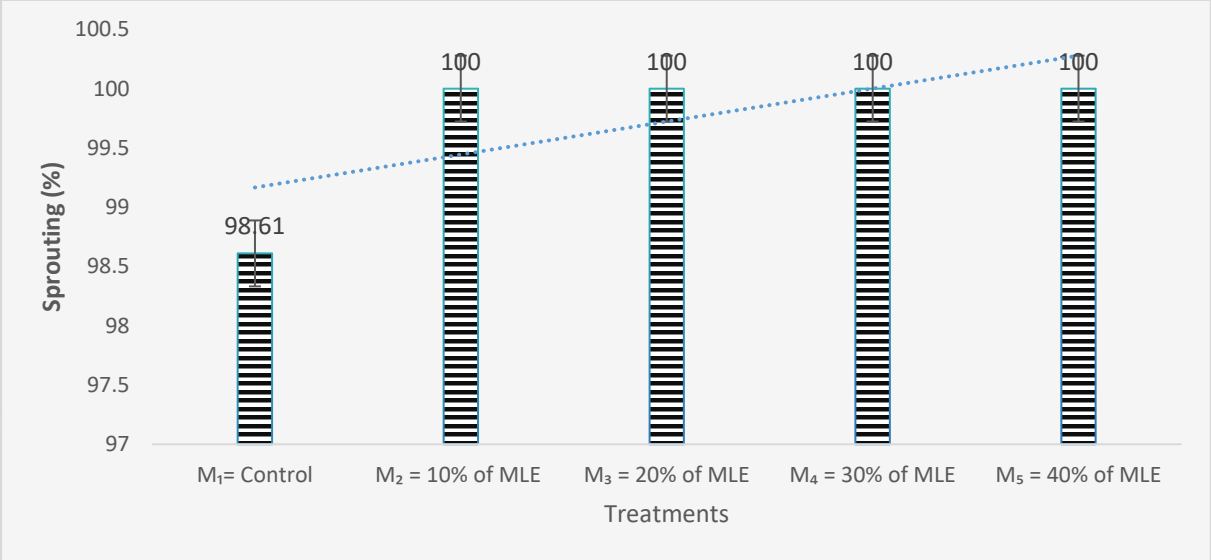


Figure no 1. Effect of Moringa Leaf Extract (MLE) on Sprouting % of china rose cuttings.

Sprouting %:

The sprouting percentages **of china rose** in response to different concentrations of Moringa Leaf Extract (MLE) and the findings are given in (Figure1)The sprouting percentage was **100%** at all concentrations of Moringa Leaf Extract (from 10% to 40%), demonstrating that Moringa Leaf Extract, even at higher concentrations, consistently promoted full sprouting. The control treatment showed slightly lower sprouting percentages, with **98.61% .**

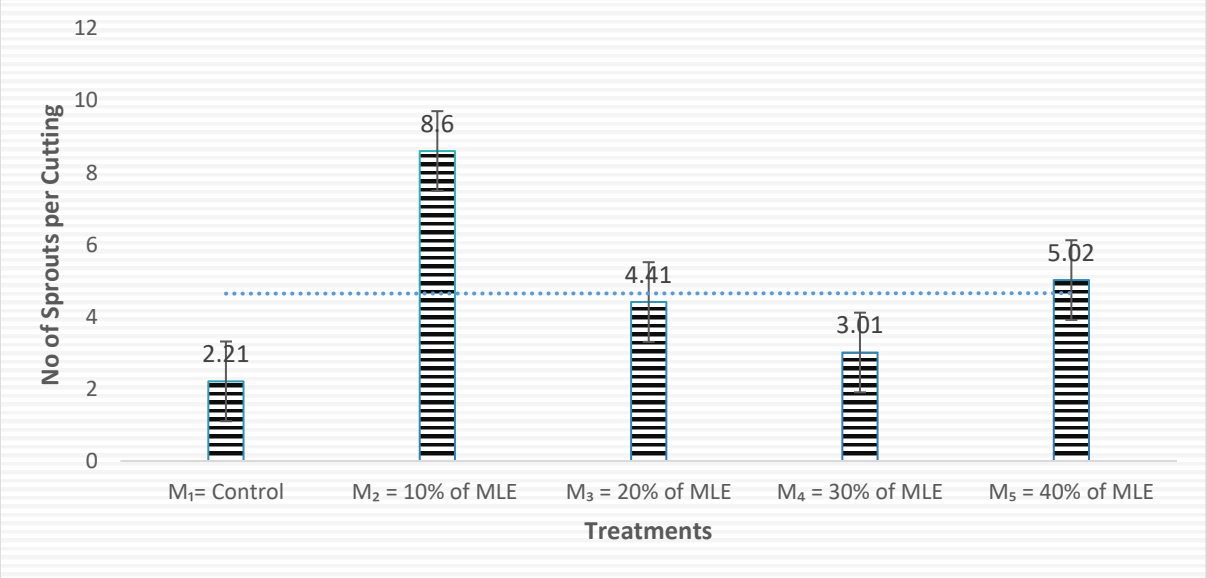


Figure no 2. Effect of Moringa Leaf Extract (MLE) on number of sprouts per cuttings of china rose cuttings.

Number of Sprouts Per Cutting:

The results regards the number of sprouts produced by stem cuttings of china rose varied in response to different concentrations of Moringa Leaf Extract (MLE) and the findings are given in (Figure2). In the control (M_1), the cuttings produced an average of 2.21 sprouts, This served as the baseline for the experiment. When the concentration of Moringa Leaf Extract was increased to 10% (M_2), the sprouting response was significantly higher. The cuttings produced the highest number of sprouts, with an average of 8.6. This indicated that 10% MLE was the most effective concentration for promoting sprouting. However, as the concentration increased further, the number of sprouts decreased. At 20% MLE (M_3), the cuttings produced 4.41 sprouts. showing a reduction in sprouting compared to the 10% concentration. Similarly, at 30% MLE (M_4), stem cuttings yielded 3.01 sprouts, This continued decline in sprouting suggests that higher concentrations of Moringa Leaf Extract were less effective at promoting growth. At the highest concentration of 40% MLE (M_5), Terminal cuttings produced 5.02 sprouts, still showing higher sprout numbers compared to the control group but lower than at the 10% concentration.

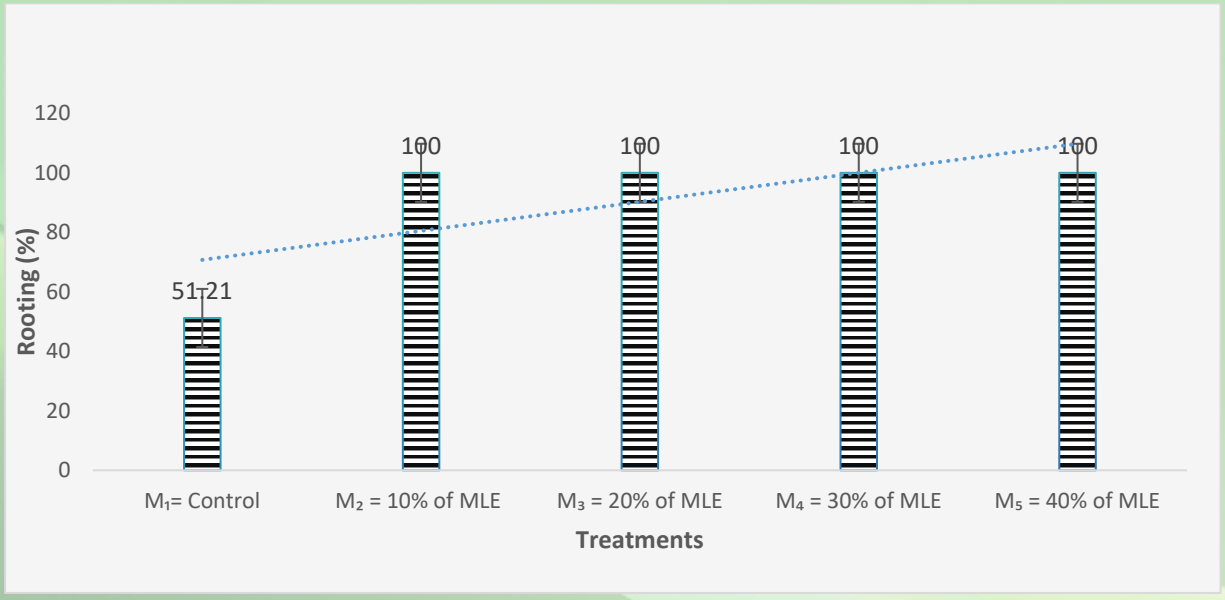


Figure no 3. Effect of Moringa Leaf Extract (MLE) on Rooting % of china rose cuttings.

Rooting percentages:

The rooting percentages stem **cuttings of china rose** in response to different concentrations of Moringa Leaf Extract (MLE) the findings are given in (Figure 4). In the **control group (M_1)**, **cuttings** had a rooting percentage of **51.21%**, indicating that rooting was limited without the use of Moringa Leaf Extract. When **10% Moringa Leaf Extract (M_2)** was applied, **cuttings** achieved **100% rooting**, showing a dramatic improvement. The same

100% rooting was observed at **20% (M3)**, **30% (M4)**, and **40% (M5)** concentrations, demonstrating that higher concentrations of Moringa Leaf Extract did not decrease rooting success.

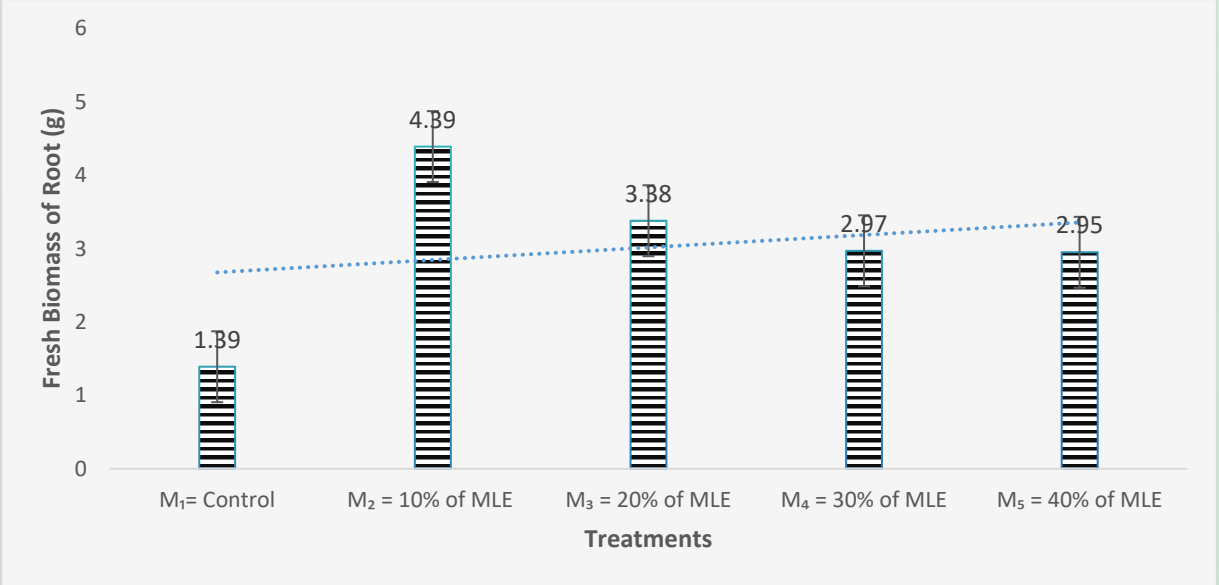


Figure no 4. Effect of Moringa Leaf Extract (MLE) on Fresh biomass of Root (g) of china rose cuttings.

Fresh Biomass of Roots (g):

The Results regards fresh biomass of roots in response to different concentrations of Moringa Leaf Extract (MLE), significant differences were observed in the stem cutting **of chna rose** the findings are given in (Figure 5). The control group (M_1) showed relatively low root biomass, with having **1.39,** establishing the baseline for the experiment.When **10% Moringa Leaf Extract (M_2)** was applied, cuttings experienced a considerable increase in root biomass. **cuttings** reached **4.39 grams**, This marked a substantial improvement compared to the control, indicating the effectiveness of the 10% MLE concentration in promoting root growth. At **20% Moringa Leaf Extract (M_3)**, the root biomass remained significantly higher than the control, with stem **cuttings** producing **3.38 grams.** While still an increase, the root biomass was somewhat lower than at the 10% concentration, suggesting a slight decline in effectiveness as the concentration of MLE increased.With **30% Moringa Leaf Extract (M_4)**, the fresh root biomass decreased further. **Terminal cuttings** produced **2.97 grams.** This decline in root biomass with increasing MLE concentration indicated that higher concentrations may not be as effective for root growth as the lower concentrations. At **40% Moringa Leaf Extract (M_5)**, **Terminal cuttings** produced **2.95 grams** of root biomass. While these values were still higher than the control group, they were lower than the biomass observed at the 10% and 20% concentrations, further suggesting that the optimal concentration for root biomass was at the lower levels of Moringa Leaf Extract.

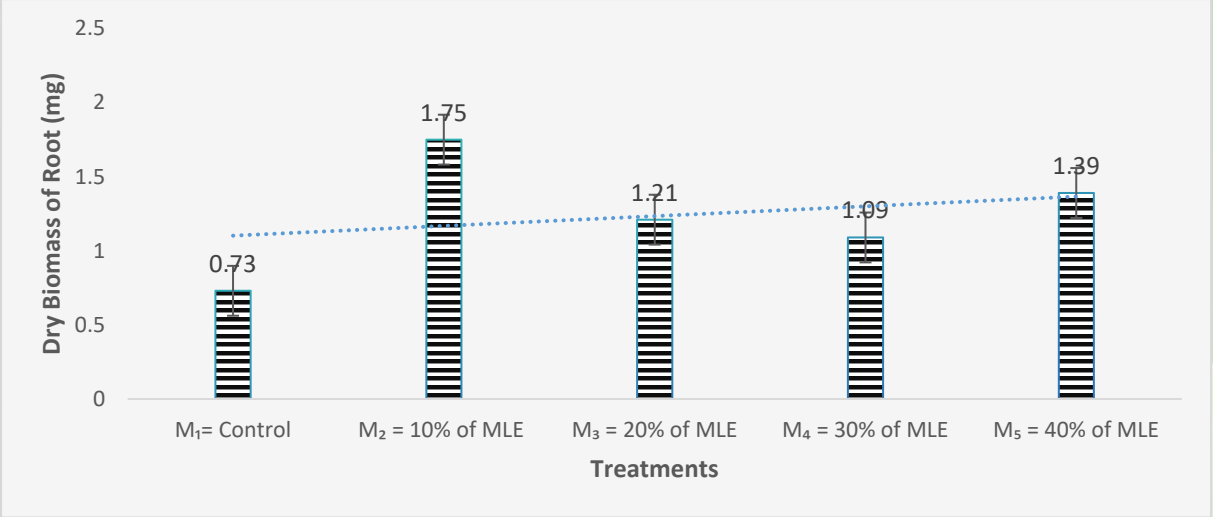


Figure no 5. Effect of Moringa Leaf Extract (MLE) on Dry biomass of Root (mg) of china rose cuttings.

Dry Biomass of Roots (mg):

The results regards the dry biomass of roots stem cutting **of china rose** in response to various concentrations of Moringa Leaf Extract (MLE) showed notable differences are given in (Figure 5). In the **control group (M_1)**, the dry root biomass was **0.73 mg**, These values served as the baseline for comparison. When **10% Moringa Leaf Extract (M_2)** was applied, stem **cuttings** experienced a significant increase in dry root biomass. **Terminal cuttings** produced **1.75 mg**, demonstrating the positive impact of Moringa Leaf Extract at this concentration.At **20% Moringa Leaf Extract (M_3)**, the dry biomass was **1.21 mg**, While both values were higher than the control, there was a slight reduction in biomass compared to the 10% concentration, suggesting a diminishing effect with higher concentrations.With **30% Moringa Leaf Extract (M_4)**, **Terminal cuttings** produced **1.09 mg**, Although these values were still higher than those in the control group, they were lower than those observed at the 10% and 20% concentrations, indicating that the effectiveness of the Moringa Leaf Extract began to decrease as the concentration increased.At **40% Moringa Leaf Extract (M_5)**, **Terminal cuttings** showed **1.39 mg**.

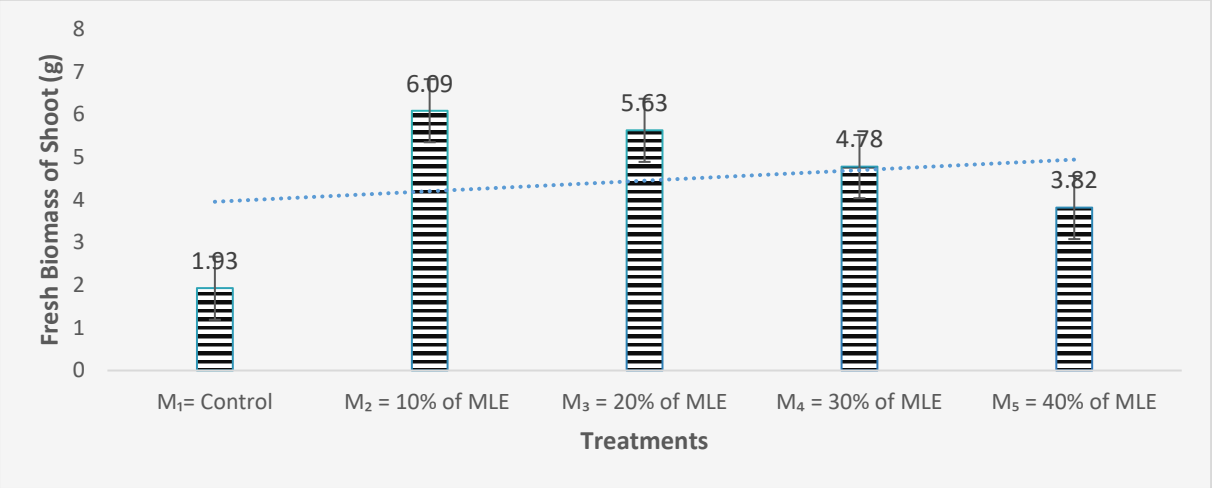


Figure no 6. Effect of Moringa Leaf Extract (MLE) on Fresh biomass of Shoot (g) of china rose cuttings.

Fresh Biomass of Shoot (g):

The results regards the fresh shoot biomass **of china rose** in response to different concentrations of Moringa Leaf Extract (MLE) the findings are given in (Figure 6). The outcomes clearly indicated an influence of MLE on shoot biomass, with the maximum biomass noted at the 10% MLE concentration (M_2). At this concentration, cuttings had a fresh biomass of 6. 09 g, This implies that Moringa leaf extract may greatly improve shoot growth. Though the 10% MLE level was most successful, more concentrations (20%, 30%, 40% MLE) resulted in a reduction in biomass for stem cutting. M_3 is 20% MLE; the biomass for terminal cuttings falls to 5. 63 g, Terminal cuttings' biomass dropped even more to 4. 78 g at 30% MLE (M_4), At the highest level of 40% MLE (M_5), though, biomass decreased once more; terminal cuttings had 3. 82 g.

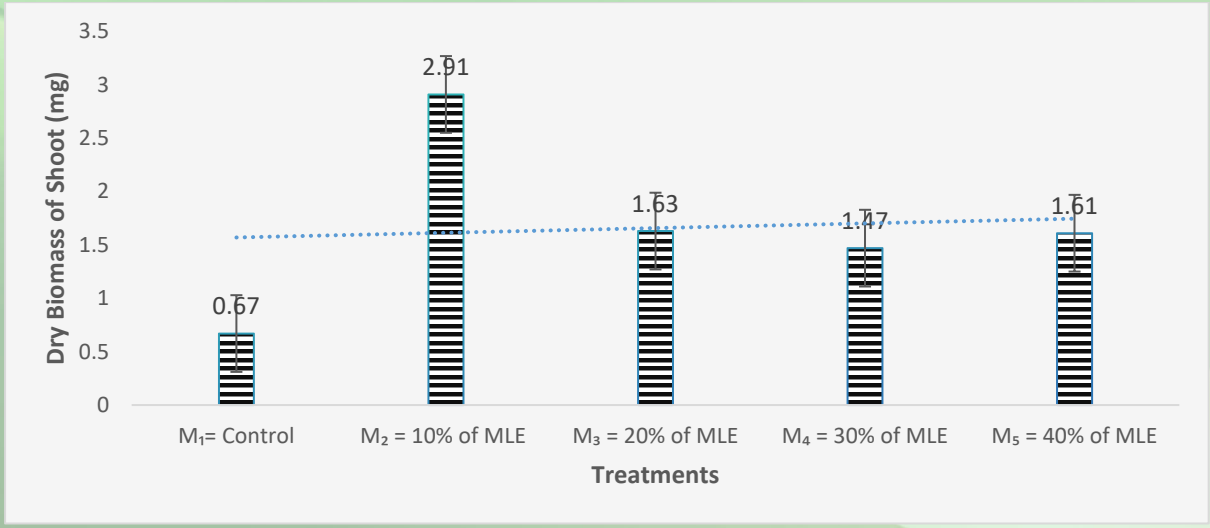


Figure no 7. Effect of Moringa Leaf Extract (MLE) on Dry biomass of Shoot (mg) of china rose cuttings.

Dry Biomass of Shoot (mg)

The results regards the Dry biomass of shoot of china rose in response to different concentrations of Moringa Leaf Extract (MLE) the findings are given in (Figure 7). Control treatment (M_1) yields 0. 67 mg terminal cut's Terminal cuttings' dry biomass rose significantly to 2. 91 mg after a 10% MLE (M_2) treatments, This suggests that terminal cuttings reacted more favorably to the 10% MLE concentration. By comparison, terminal cuttings saw a small decrease in dry biomass that dropped to 1. 47 mg at this level.With the highest 40 percent MLE (M_5), terminal cuts showed a small dry biomass rise to 1. 61 mg. This indicates that although higher MLE levels first raised biomass in sub terminal cuts, there was a reduced impact at the 40 percent level.

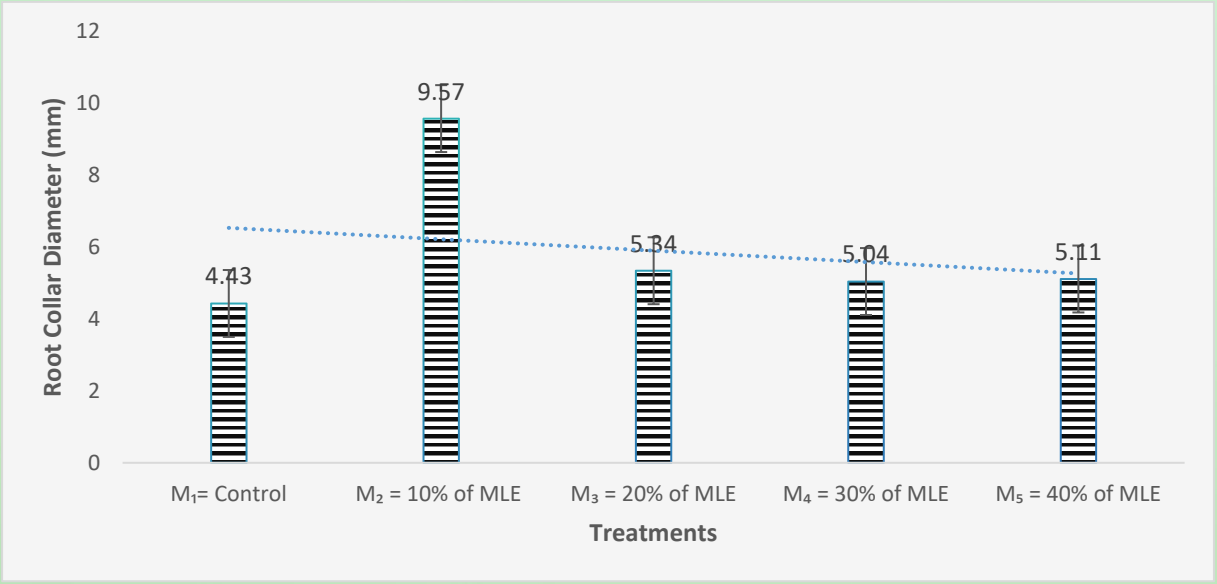


Figure no 8. Effect of Moringa Leaf Extract (MLE) on Root Collar Diameter (mm) of china rose cuttings.

The results regards Root Collar Diameter (RCD) of stem cutting of china rose treated with various concentrations of Moringa leaf extract (MLE)are shown in (figure 8). At the control level (M_1), the root collar diameter for terminal cuttings was 4.43 mm, On the application of 10% MLE (M_2), cuttings showed a significant increase in root collar diameter. Terminal cuttings showed a marked increase to 9.57 mm. This improvement is quite huge, and there is a huge positive effect in the development of the root collar by Moringa leaf extract at 10%. At the increasing concentration of 20% MLE (M_3), root collar diameter declined to 5.34 mm for terminal cuttings, Further reduction in root collar diameter for terminal cuttings was recorded by application of 30% MLE (M_4), and this came to be 5.04 mm while that of sub-terminal cuttings slightly decreased to 10.71 mm. This means higher concentrations of Moringa leaf extract did not show further improvement for terminal cuttings and only marginally affected the sub-terminal cuttings. At the highest concentration, 40% MLE (M_5), a slight increase to 5.11 mm in the terminal cuttings were observed. It indicates that though higher MLE concentrations failed to increase root collar diameter of the terminal cuttings positively.

Discussion

The current work sought to assess the effects of Moringa Leaf Extract (MLE) on sprouting and growth reactions of Hibiscus rosa-sinensis (China Rose) stem cuttings. Outcomes of this experiment indicate that MLE has a significant effect on promoting sprouting, rooting, and growth characteristics in China Rose cuttings with a different level of efficacy based on the concentration of MLE. The results of this research indicated that the percentage of sprouting of China Rose cuttings was 100% at all Moringa Leaf Extract concentrations, ranging from 10% to 40%, which indicates the high potential of MLE in promoting sprouting. These findings are in agreement with research that has indicated the positive impact of Moringa on seed germination and plant sprouting. Maishanu et al. (2017) showed that Moringa leaf extract was able to boost sprouting in several plant species owing to its high growth hormone content. The control treatment with the slightly lower percentage of sprouting (98.61%) also complements the positive effect of MLE on sprouting. This uniform sprouting response at all MLE concentrations indicates its function in inducing early growth processes irrespective of oncentration and implies that MLE may be a useful tool for enhancing China Rose propagation rates. The highest number of sprouts per cutting was achieved with the use of 10% MLE (M_2), where the cuttings averaged 8.6 sprouts, the highest across all treatments. This result is in line with other studies that have established the beneficial role of Moringa extract

on shoot growth and plant development (khan et al., 2020). The decrease in the number of sprouts with increasing MLE concentrations (20%, 30%, and 40%) may reflect a decreasing return at increased concentrations. This trend is consistent with the findings of khan et al. (2017), who hypothesized that elevated concentrations of plant growth regulators can cause phytotoxicity or decreased efficacy because of excess growth-promoting substance accumulation. So, a concentration of 10% MLE seems to be most effective for induction of sprouting and further shoot growth in China Rose.

The experiment proved that Moringa Leaf Extract greatly enhanced China Rose cutting rooting percentage with 100% rooting obtained on all concentrations, including the control. This aligns with Rajani et al. (2024) who found enhanced root growth in several plants exposed to Moringa leaf extract. Nevertheless, although MLE enhanced rooting at all concentrations, the similar percentages of uniform rooting across treatments indicate other factors, rather than MLE concentration, like environmental conditions and the inherent genetic makeup of the plant, could be involved in successful rooting. These findings suggest that MLE's influence on rooting can be less concentration-sensitive than its effect on sprouting since the rooting process tends to saturate at all the tested concentrations. The research noted drastic variation in the root and shoot biomass in accordance with the use of Moringa Leaf Extract. At 10% MLE, cuttings recorded the greatest fresh and dry biomass for roots and shoots. These findings agree with earlier research that noted the growth-promoting role of Moringa based on its high vitamin, mineral, and plant growth regulator content (Sonbarse et al., 2020). The enhancement of root and shoot biomass at reduced concentrations of MLE indicates improved overall growth and development, with the most effective being the 10% concentration.This is consistent with the fact that reduced levels of growth-stimulating substances are more effective in stimulating plant growth than elevated levels, which might bring about toxicity or compromise nutrient uptake efficiency (Bano et al., 2022).

The reduction of biomass at the higher concentrations (30% and 40%) may be an indication of the plant's reaction to excess growth promoter compounds. High levels of Moringa Leaf Extract might cause nutrient imbalance, cellular stress, or suppression of normal metabolic processes, which may result in reduced growth. These results indicate that, although Moringa Leaf Extract is a very effective plant growth promoter, the most suitable concentration for stimulating biomass accumulation in China Rose is approximately 10%.

The root collar diameter (RCD) improved considerably at the 10% MLE concentration, with the cuttings exhibiting a notable increase in RCD than the control group. This suggests that Moringa Leaf Extract can promote the structural growth of the roots, especially root collar development, which is an important consideration for root stability and nutrient absorption. But as the level of MLE intensified, the influence on root collar diameter decreased, especially at 20%, 30%, and 40% levels. This trend is consistent with what was recorded for biomass, where elevated levels of MLE yielded worse growth results.The growth-promoting properties of Moringa Leaf Extract noted in this study are due to its high concentration of growth hormones like cytokinins, auxins, and gibberellins that are responsible for cell division, root initiation, and shoot elongation (Basra et al., 2016).

Acknowledgements

The authors are deeply grateful to the research team for their steadfast support, expert guidance, and significant contributions throughout this study. Their dedication and efforts have played a crucial role in the success of this study.

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ID: 639

Effect of different level of macro nutrients on the growth and development of spinach (Spinacia oleraceae L.)

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Abstract

This study investigates the effect of varying levels of macro nutrients on the growth and development of spinach (Spinacia oleracea L.) using a Completely Randomized Design (CRD) with two varieties: Sindhi and English spinach. Conducted during 2024, the experiment utilized a total of six nutrient combinations, including control, NPK (3g/L, 4g/L, 5g/L), and Calcium Nitrate (1g/L), applied to two per pot across replicated treatments. Parameters such as seed germination percentage, germination index, plant height, leaf metrics, root characteristics, and chlorophyll content were assessed. Results indicated a significant enhancement in growth metrics with NPK (3g/L) plus Calcium Nitrate (1g/L), particularly for Sindhi spinach, where it exhibited a germination rate of 95.16% and an increase in chlorophyll to 64.86. Conversely, higher concentrations of NPK negatively affected germination and growth in both varieties, suggesting that balanced nutrient application is crucial for optimal spinach development. This investigation underscores the importance of macro nutrients in enhancing spinach yield, contributing valuable insights for growers aiming to maximize crop productivity.

Key Words: Spinach1, Macro Nutrients2, Growth3, Development4

ID: 640

Proximate And Phytochemical Propeties of Bread Prodcued from Pro-Vitamin A Rich Cassava, Africa Walnut and Tigernut Composite Blends

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Abstract

Pro vitamin A rich sources such as; cassava, Africa walnut and tigernut composite flour were used in the production of bread, where 100 % pro vitamin A rich cassava bread coded AP stands for (-ve control) sample HP had a formulation ratio of (90:5:5 %) while, sample IP produced from 100 % wheat flour serves as the positive control sample respectively. the pro vitamin A rich bread samples were analyzed for its proximate and phytochemicals properties. The results obtained for proximate composite of the bread samples had a moisture content ranged from (21.04 – 23.42 %), ash (1.55 - 3.45 %), crude fibre (2.33 - 2.96 %), crude fat (4.33 - 8.27%), crude protein (7.51 - 11.89 %) and carbohydrate (52.41 – 59.89 %) which showed that there was a significant difference among the samples coded HP, AP and IP at ($P<0.05$) level of probability ,which revealed that sample HP were significant in terms of ash, fiber, Fat and protein content and most highest in proximate composition with low moisture content compared with sample AP and IP respectively. The results the phytochemical properties of composite bread samples revealed that phenolic content had a mean value ranged from (803.89 - 905.70µg), tannin (107.60 - 147.65 µg), flavonoid content ranged from (201.78 - 339.85 µg), glycoside (1.83 – 1.83 %), alkaloid (3.23 - 3.54 %) and saponins (5.00 - 5.06 %) where sample HP had the highest mean value of phenol, tannin, flavonoids and glycoside, this properties could provide additional health benefits to the consumers. A bread prepared from a blends of Pro-vitamin A rich cassava, Africa walnut and tigernut flour could potentially be used to address protein-energy malnutrition and hence reduce the risk of vitamin A deficiency among vulnerable groups especially in developing countries.

Key words: *Pro vitamin A rich cassava, Africa walnut, Tigernut, phytochemical, antioxidant and proximate composition.*

ID: 641

Integrated use of Fertilizers and Bio-Stimulant affect the Growth and Seedling Development of ChiliMaria

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Abstract

Common beans, being a nutritionally rich and widely consumed legume, require the evaluation of diverse genotypes to identify those with superior agronomic traits. This study aimed to evaluate the morphological variation among 16 common bean (*Phaseolus vulgaris* L.) genotypes collected from diverse regions of Azad Jammu and Kashmir and NARC Islamabad, Pakistan. The experiment was conducted on August 15, 2023, at the Vegetable Crop Research Program field in Islamabad. The 16 genotypes were replicated three times, resulting in a total of 48 plants, and arranged in a Randomized Complete Block Design (RCBD) to ensure uniformity and precision. Genotypes were assessed based on growth habit, leaf area, leaf shape, number of nodes, stem and flower color, number of flowers, days to flowering, days to fruit setting, and chlorophyll content. Analysis of variance (ANOVA) revealed significant differences among genotypes for most traits. Genotype AJKS8 (15) exhibited superior performance with the greatest plant height, highest number of nodes, and maximum flower production. In contrast, genotype 37753 (1) recorded the shortest height and smallest leaf area. All genotypes displayed ovate leaf shapes, with variation in stem and flower color, ranging from light green to dark stems and white to purple flowers. Genotype 37886 (10) flowered earliest, while genotype 37789 (11) showed the longest flowering duration. Least Significant Difference (LSD) analysis categorized genotypes into distinct groups, confirming considerable genetic diversity. These findings provide valuable insights for selecting high-performing landraces and contribute to future common bean breeding and improvement programs.

Key words: *Common Beans genotypes, Morphological characteristics, Genetic diversity*

ID: 642

Morphological Characterization of Common bean (*Phaseolus vulgaris* L.) Genotypes at Early Growth Stage

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Abstract

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Key words: *Common Beans genotypes, Morphological characteristics, Genetic diversity*

ID: 643

A Business Model for Community-Based Vegetable Seed Production in Bangladesh

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Abstract

Agriculture remains the backbone of Bangladesh's economy, with the vegetable sector critical for food and nutritional security. However, challenges like poor access to quality seeds, import dependency, and weak market linkages constrain productivity and farmer incomes. This paper presents a sustainable business model for community-based vegetable seed production, developed through a partnership between the Bangladesh Agricultural Research Institute (BARI), Sara Bangla Krishok Society (SBKS), and Dutch Bangla Bank PLC. The model engages smallholder farmers in quality seed production through a cooperative framework, thereby creating a comprehensive value chain that spans from cultivation to marketing. Implemented through the project "Community-Based Sustainable Vegetable Production," it involved 137 farmers cultivating 31 BARI-released varieties across 20.50 hectares, producing 16,923.7 kg of seeds with productivity reaching 927.78 kg/ha. The business model incorporates key components: (1) farmer capacity building through training and exchange visits, (2) quality assurance via BARI's technical supervision of seed processing and certification, and (3) financial support by Dutch Bangla Bank PLC and (4) market access through SBKS's network of 115 producer organizations serving 8,000+ farmers. Post-production activities—seed extraction, drying, quality testing (germination, purity, vigor), packaging, labeling, and storage—were rigorously supervised by BARI breeders. The SBKS cooperative network facilitated market linkages, distributing seeds to member farmers and institutional buyers like ActionAid Bangladesh and Udayankur Seba Sanstha (USS). This vertically integrated approach demonstrates strong commercial viability, with seeds marketed both to cooperative members and institutional buyers like ActionAid Bangladesh. The model reduces import dependence by 30-40% while increasing farmer incomes by 25-35%. Its scalability is evidenced by expansion across climate-vulnerable Barind and coastal regions. The business model offers a sustainable solution to Bangladesh's seed security challenges, combining farmer empowerment with market-oriented production. Policy support for scaling this model could transform Bangladesh's vegetable seed sector while contributing to SDGs 1, 2, and 8.

Keywords: *Agricultural business model, seed production, cooperative farming, value chain development, sustainable agriculture, Bangladesh.*

ID: 644

Selection of High-Yielding Watermelon Lines for Enhanced Food and Nutritional Security in Bangladesh

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Abstract

This study evaluated 10 watermelon germplasm lines alongside check variety (BARI Tarmuj-1) at the Olericulture Division of HRC, BARI, Gazipur during February-May 2024 to identify superior genotypes for farmers' cultivation. Significant variations were observed in key agronomic and quality parameters among the tested lines. Vine length ranged from 4.0-5.10 m, while critical fruit quality traits showed substantial variation: flesh thickness (13.0-31.0 cm), rind thickness (1.7-2.5 cm), and total soluble solids (TSS) content (10.50-13.60%). Fruit yield per plant varied considerably (11.85-18.49 kg), with five promising lines outperforming the check variety: CL009D (18.49 kg), CL009B (18.36 kg), CL009C (18.10 kg), CL009A (17.32 kg), and CL008 (17.24 kg). The selected lines combine high yield potential with superior quality attributes, particularly the optimal flesh-to-rind ratio and elevated TSS content (>13%), indicating enhanced sweetness and nutritional value. These characteristics make them ideal for both fresh consumption and processing, addressing Bangladesh's growing demand for nutrient-dense fruits. The identification of these high-performing genotypes provides valuable breeding material for developing improved watermelon varieties that can boost productivity by 25-35% compared to existing varieties. This research contributes directly to food and nutritional security by offering farmers access to superior genetic material with better yield stability and quality. The selected lines demonstrate potential for climate resilience and market preference, aligning with national agricultural development goals. Further multilocation trials are recommended to validate performance across different agroecological zones before official release.

Keywords: *Watermelon breeding, germplasm evaluation, fruit quality, yield improvement, nutritional security, Bangladesh.*

ID: 645

Effect of plant-derived additives on bioactive properties of fermented dairy products : A review

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Abstract

Food bioactives are compounds that exert physiological benefits promoting health and preventing effects of diseases in the human body through their antioxidant, antibacterial, anticancer, antidiabetic and analgesic properties. Plant-derived bioactive owing to the growing researcher's interest due to their abundance, low cost and wider acceptability. This growth is fuelled by technological innovations through the development of new products by fortifying plant-based sources. Fermented dairy products are of great importance due to their special characteristics, are an excellent matrix for the incorporation of ingredients and benefits on the hosts intestine and microbiome, immunomodulation and anti-allergenic effects. This review has extensively assessed the recent knowledge on the quantitative and qualitative enhancement of the nutritional value of fermented milk products by the enrichment of plant-based bioactive compounds. Fermented dairy products including yoghurt, curd, kefir, sour cream, cheese, buttermilk and drinking yoghurt have popularly fortified with different fruits, vegetables, herbs, spices, cereals and nuts. The findings of this review demonstrated that the bioactivity of fermented dairy products has increased with the incorporation of fruits, since they contain the majority of bioactive compounds such as carotenoids, polyphenols, dietary fibre and fatty acids. Fermented dairy products supplemented with herbs are typically high in polyphenols, fatty acids and carotenoids. It was also shown that spices enriched dairy products had more polyphenols, carotenoids and dietary fibre than unfortified dairy products. Nuts and oil crops, such as walnuts and hazelnuts have enhanced the fatty acid content of yoghurts. Taken together, these findings suggest that the role of bioactive compounds in promoting antioxidant, antimicrobial, antihyperglycemic, anti-inflammatory and antiradical effects. In future, it would be interesting to assess more studies on the synergetic effect between the natural bioactive compounds and fermented dairy products to enhance growing demand and potential health benefits.

Key Words: *Fermented Dairy Products1, Health Benefits2, Nutritional Value3, Plant-based Bioactives4*

Introduction

The consumption of fermented dairy products has seen a significant and steady increase over recent years, largely due to their enhanced digestibility, extended shelf life, improved nutritional and organoleptic properties, and the reduction of antinutritional compounds generated during fermentation. Certain strains of lactic acid bacteria are capable of metabolizing antinutritive components such as lactose and galactose, thereby offering protection against lactose intolerance and galactose accumulation (García-Burgos et al., 2020). Popular fermented dairy products include yogurt, curd, kefir, sour cream, cheese, buttermilk, and drinkable yogurt, all of which have been widely studied for their functional and health-promoting properties.

During fermentation, a variety of bioactive compounds such as vitamins, gamma-aminobutyric acid (GABA), bioactive peptides, bacteriocins, enzymes, conjugated linoleic acid (CLA), and exopolysaccharides are produced. These compounds have demonstrated potential roles in cancer prevention, blood pressure regulation, and type 2 diabetes management (Linares et al., 2017; Lee et al., 2020). Additionally, the increasing demand for fermented dairy products among individuals with lactose intolerance further highlights their functional appeal.

Despite the nutritional richness of fermented dairy products, some micronutrients such as zinc may be present in insufficient quantities (Jalal et al., 2016), and processing methods like heat treatment can degrade heat-sensitive nutrients. Moreover, fermentation may sometimes reduce antioxidant activity in products like yogurt (Dabija et al., 2018). As a result, fortification becomes essential to maintaining or enhancing the overall nutritional profile of these products.

The growing interest in functional foods—defined as those that provide health benefits beyond basic nutrition when consumed as part of a regular diet (Products & Foods, 1998)—has driven innovation in the dairy sector. With rising concerns over the negative effects of synthetic additives on the nervous and gastrointestinal systems, and their potential carcinogenic risks (Alenisan et al., 2017), researchers have turned their attention to natural plant-based additives rich in bioactive compounds.

Bioactive compounds—non-essential nutritional molecules present in small amounts—offer multiple health benefits, including antioxidant, antimicrobial, antidiabetic, anticancer, and analgesic effects (Septembre-Malaterre et al., 2017). These include phytosterols, polyphenols, unsaturated fatty acids, dietary fiber, and pigments such as carotenoids, anthocyanins, chlorophylls, and lycopene, commonly found in herbs, spices, fruits, vegetables, and green tea. Incorporating these compounds into dairy products can enhance both nutritional quality and product shelf life, while contributing positively to consumer health.

To effectively enrich dairy products with these bioactive compounds, a range of extraction and encapsulation techniques are employed, such as Soxhlet extraction, ultrasound-assisted extraction, supercritical fluid extraction, spray drying, coacervation, and freeze drying (Martins et al., 2017). However, challenges such as high dosage requirements, low bioavailability, unclear mechanisms of action, and limited availability of raw materials may arise. Advanced approaches involving biotechnology, nanotechnology, active packaging, and sustainable sourcing have been proposed to overcome these issues (Prakash et al., 2017).

Globally, the nutritional and therapeutic potential of natural sources has stimulated extensive research in this domain. Studies have shown that fortification with plant-based antioxidants can effectively reduce oxidation in dairy products with fewer adverse effects compared to synthetic additives (Alenisan et al., 2017). While essential oils have demonstrated positive antioxidant and antimicrobial properties, they may also affect sensory attributes negatively (Mishra et al., 2020). Similarly, the incorporation of grape extracts has improved antioxidant activity in dairy matrices but negatively impacted flavor (Kandylis et al., 2021).

Despite these advancements, research on the incorporation of tropical plant-based additives into fermented dairy products in Sri Lanka remains limited. The local application of such additives, which are rich in bioactive compounds, holds considerable potential for improving public health. Although antioxidant and antimicrobial properties have been well-documented, there is a notable lack of studies on the anti-tumor, anti-carcinogenic, anti-mutagenic, and immunomodulatory effects of these compounds when used in dairy product fortification (Prakash et al., 2017).

The primary aim of this review is to critically evaluate how natural additives rich in bioactive compounds can enhance the nutritional and functional quality of fermented dairy products, both quantitatively and qualitatively. Additionally, this review seeks to identify promising plant-based sources for fortification and to assess their impact on sensory, nutritional, and health-related attributes. A survey of Sri Lanka's dairy industry was also conducted to understand current practices and perceptions regarding the use of bioactive-rich natural additives in fermented dairy products. Ultimately, this article presents a comprehensive overview of fermented dairy products, the importance of fortification, the functional potential of plant-derived bioactive compounds, and the challenges and prospects in this emerging field

Materials and Methods

A comprehensive literature review was conducted using the Web of Science database to gather relevant studies aligned with the research objectives. A total of 291 articles were initially selected based on specific keywords related to fermented dairy products, fortification, and bioactive compounds. To maintain relevance and consistency, articles published before 2016 and those written in languages other than English were excluded.
Following a thorough screening process, 40 articles that met the inclusion criteria were selected for detailed review and analysis. The selected studies were assessed based on their contribution to understanding the nutritional, sensory, and health-related impacts of incorporating bioactive compound-rich natural additives into fermented dairy products.
Due to the extensive body of literature, the focus was narrowed to four major classes of bioactive compounds commonly studied in food fortification: polyphenols, carotenoids, dietary fiber, and polyunsaturated fatty acids. Similarly, among the wide range of fermented dairy products, cheese, yogurt, kefir, butter, and fermented milk were selected due to their global popularity and variation in formulation.
The selected articles were first qualitatively analyzed to understand the role and impact of each bioactive compound on nutritional enhancement, sensory attributes, and potential health benefits. Subsequently, the magnitude of observed effects was assessed and summarized, allowing for a more structured comparison of the outcomes across different studies.

Results and Discussion

Yogurt

Lactobacillus bulgaricus and *Streptococcus thermophilus* are the primary starter cultures used in the fermentation of cow's milk to produce yogurt. Yogurt is a rich source of minerals such as calcium, magnesium, phosphorus, and zinc, along with essential vitamins including B1, B2, B12, and D. It offers several health benefits, including enhanced lactose digestion, improved bioactive compound profiles, and increased bone mineral uptake (Gómez-Gallego et al., 2018).

Yogurt is particularly beneficial for individuals with lactose intolerance due to the partial hydrolysis of lactose by bacterial β-galactosidase. Furthermore, it plays a preventive role in various health conditions, including cancer, hypertension, and diarrhea, and supports gut microbiota balance. The unique flavor of yogurt is attributed to the volatile compounds produced by fermentative bacteria.

Yogurt can be categorized based on fat content, physical structure, and flavoring (Chandan, 2017):

Fat content: High-fat, reduced-fat, low-fat yogurt
Physical structure: Set yogurt, stirred yogurt
Flavorings: Plain yogurt, flavored yogurt

Figure 1. Classification of yogurts (Source: Chandan, 2017)

The general processing steps for yogurt production include standardization and fortification, homogenization (65°C, 1.8×10^4 kPa), heat treatment (85°C for 30 minutes), cooling to incubation temperature (42°C), and inoculation with the starter culture.

Figure 2. Flow diagram of yogurt processing (Source: Chandan, 2017)

The current study affirms that yogurt can be effectively enriched with bioactive compounds through natural additives (Jaster et al., 2018; Šeregelj et al., 2019, 2021a).

Cheese

Cheese is a versatile dairy product available in cooked and uncooked varieties. Over time, its nutritional value, texture, and flavor have improved. Cheese offers numerous health benefits, such as supporting bone and dental health, regulating blood pressure and cholesterol, and maintaining vascular and gut health (Martins et al., 2017).

Cheese can be made from various milk sources including cow, goat, sheep, and buffalo milk. Based on processing parameters, cheese is classified into several types (Hammam & Ahmed, 2019):

Processing method: Cheddar, cream cheese, cottage cheese
Composition: Salted, unsalted, high-fat, low-fat cheese
Maturation method: Acid-ripened, enzymatic ripened
Starter culture: Mold-ripened, bacteria-ripened cheese

The general processing steps for cheese involve standardization and pasteurization, inoculation with cultures, renneting, curd cutting, cooking (37°C–42°C for 40 minutes), salting, forming, pressing, and aging.

This study demonstrates that cheese can be successfully fortified with natural additives rich in bioactive compounds (Balabanova et al., 2020; Ghendov-Moşanu et al., 2020; Masmoudi et al., 2020).

Kefir

Kefir, an emerging functional dairy product, exists in two main forms: milk kefir and water kefir (Guzel-Seydim et al., 2021). It contains high levels of organic acids, sugars, esters, and alcohols, contributing to its distinct flavor and texture.

Kefir is produced by fermenting milk with kefir grains or lyophilized cultures that primarily consist of lactic acid bacteria and yeast. Nutritionally, kefir is abundant in B-complex vitamins (B1, B2, B6, B12), essential amino acids (e.g., phenylalanine, tyrosine, leucine, glycine), and minerals such as magnesium, potassium, and calcium (Vicenssuto & de Castro, 2020a).

Due to its probiotic, prebiotic, antibacterial, anti-inflammatory, and antioxidant activities, kefir offers protective effects against obesity, hypercholesterolemia, and cancer while promoting longevity. The study confirms that kefir can be effectively enriched with natural additives containing bioactive compounds (Vicenssuto & de Castro, 2020a, 2020b).

Butter

Butter typically contains 80–83% fat and up to 400 different fatty acids. It is widely used both as a spread and a cooking fat. Butter is produced by churning milk or cream, which disrupts fat globules and forms a water-in-oil emulsion, separating butter granules from buttermilk.

While cow milk is most commonly used, butter can also be derived from sheep, goat, and buffalo milk (Mehdizadeh et al., 2019). Chemically, butter is rich in fat, protein, milk sugars, and water. However, it is highly susceptible to spoilage through lipid oxidation and microbial contamination, requiring stringent storage conditions (El-Hadad & Tikhomirova, 2018).

This study supports that butter can also be enriched successfully with bioactive compounds via natural additives (Mehdizadeh et al., 2019; Vidanagamage et al., 2016).

Importance of Fortification of Fermented Dairy Products

Fermented dairy products are nutrient-dense, supplying protein, calcium, vitamins (especially B12 and riboflavin), and essential minerals. Individuals with lactose intolerance can tolerate fermented dairy due to bacterial conversion of lactose into lactic acid. Additionally, these products exhibit antibacterial, antitumor, and immunomodulatory properties (Savaiano & Levitt, 1984).

Fortification improves the nutritional profile of fermented dairy products, making them more functional and health-promoting. Moreover, the matrix properties of dairy products (texture, composition, and pH) play a crucial role in the efficiency and stability of added bioactive compounds.

Bioactive Compounds in Natural Sources

Bioactive compounds are secondary plant metabolites that contribute to a plant's adaptability and survival, though not directly involved in growth or reproduction. These compounds include phenolics, alkaloids, terpenes, and phytosterols (Galanakis & Drago, 2022).

Phenolic compounds, in particular, are further classified into flavonoids and non-flavonoids (Kamiloglu et al., 2021).

Figure 5. Classification of bioactive compounds (Source: Khezerlou & Jafari, 2020)

Extraction methods for these compounds include conventional techniques like Soxhlet and hydrodistillation, and advanced methods such as ultrasound-assisted extraction (UAE), microwave-assisted extraction (MAE), supercritical fluid extraction (SFE), pressurized liquid extraction (PLE), and pulsed electric field extraction (PEF).

Phenolic Compounds: Abundance, Bioactivity, and Application in Functional Foods

Phenolic compounds represent the most abundant class of secondary metabolites in plants, characterized by the presence of one or more hydroxyl groups attached to aromatic rings (Ayad & Akkal, 2019). These compounds are widely distributed among various plant species and are classified into several subgroups, including flavonoids, phenolic acids, lignans, stilbenes, and tannins.

Phenolics are known for their diverse biological activities. One of their notable functions is their anti-inflammatory property, which contributes significantly to the prevention of cardiovascular diseases. This effect is primarily exerted through the inhibition of platelet aggregation and modulation of smooth muscle cell activity (Guasch-Ferré et al., 2017). Furthermore, phenolics exhibit antidiabetic effects by enhancing glucose uptake in peripheral tissues and reducing insulin resistance through improved insulin sensitivity (LS & NJA, 2016). Their anti-obesity potential is associated with the suppression of adipocyte proliferation, stimulation of lipolysis, appetite regulation, and reduction of inflammation in adipose tissue (LS & NJA, 2016).

The anticancer potential of phenolic compounds is also well documented. They exert protective effects by scavenging free radicals, inducing detoxifying enzymes involved in xenobiotic metabolism, regulating gene expression, and modulating several signaling pathways involved in DNA repair, apoptosis, and cell invasion (Lutz et al., 2019; Yen et al., 2020).

Recent research has explored the functional properties of phenolics in food systems. Masmoudi et al. (2020) reported that the addition of 30% strawberry pulp to a food matrix resulted in a significant increase in anthocyanin content by 2.99 mg/100 g, along with enhanced antioxidant activity measured by DPPH (9.19 mg GAE/mL) and ABTS (0.38 mg GAE/mL) assays. Although a decrease in anthocyanin content was observed during storage, the antioxidant activity remained relatively stable.

In a comparative study, Muniandy (2016) found that yoghurt enriched with green tea exhibited the highest total phenolic content (526.34 mg GAE/mL) compared to those enriched with white tea (394.12 mg GAE/mL) and black tea (294.67 mg GAE/mL), likely due to the higher catechin and epicatechin content in green tea. However, storage over two weeks led to a significant decline in phenolic content across all samples. Antioxidant activity, evaluated by DPPH RSA and FRAP, was highest in green tea yoghurt, while black tea yoghurt showed superior antioxidant potential in the FIC assay. These variations may reflect the differences in primary and secondary antioxidant capacity measured by these methods.

Josipović et al. (2015) demonstrated that the addition of dried dill significantly increased the phenolic content of cheese to 37.8 mg GAE/100 g, surpassing that of cheese fortified with parsley, pepper, garlic, or rosemary. However, this increase in phenolic content did not correspond with a higher antioxidant effect. The discrepancy was attributed to several factors, including pH, temperature, phenolic structure, amino acid composition, and potential interactions between phenolics and proteins. Additionally, the capacity of certain reagents to react with non-phenolic compounds may influence the accuracy of antioxidant measurements.

Vidanagamage et al. (2016) investigated the incorporation of cinnamon extract into butter and observed an increase in total phenolic content to 135.62 µg GAE/mg and antioxidant activity to 38.73%, highlighting the potential of spice extracts in enhancing the functional properties of dairy products.

Kabakcı et al. (2020) examined kefir enriched with anthocyanin-rich fruit juices and found that the addition of 25% black mulberry juice led to the highest anthocyanin content (404.5 mg/L) compared to pomegranate, strawberry, and black carrot juices. However, anthocyanin degradation and co-pigmentation during storage led to a significant reduction (32.1%) in anthocyanin content. The antioxidant effect was associated with the anthocyanin content of black mulberry, although no notable antimicrobial activity was detected.

Contradictory findings were reported by Kiros et al. (2016), who found no increase in phenolic content in carrot juice-enriched yoghurt compared to the control, contrary to results by Pandey et al. (2021). In fact, a slight decrease from 37 mg GAE/kg in the control to 35.75 mg GAE/kg in the fortified sample was recorded. Possible explanations include differences in carrot varieties, agronomic practices, storage conditions, and processing techniques used prior to analysis.

Carotenoids

Carotenoids are lipid-soluble secondary metabolites widely distributed in nature, especially in plants, where they play essential roles in photosynthesis and photoprotection. From a nutritional perspective, carotenoids are recognized for their health-promoting properties, including provitamin A activity, antioxidant potential, and disease-preventive roles (Karpioski et al., 2022).

Structurally, carotenoids are composed of isoprene units forming C40 terpenoids, and they are typically classified into two main groups: carotenes (hydrocarbon carotenoids, such as α-carotene, β-carotene, and lycopene) and xanthophylls (oxygenated carotenoids, including lutein and bixin). Carotenes are characterized by non-polar structures, while xanthophylls contain polar groups, making them more reactive to oxidation. Among these, lycopene has the simplest linear structure, whereas α- and β-carotenes possess cyclic ends. The differentiation between α- and β-carotene arises from the position of the double bond in the cyclic group (Karpioski et al., 2022).

Carotenoids play crucial roles in quenching singlet oxygen and scavenging reactive oxygen species (ROS), attributed to the conjugated double bonds in their polyene chain. This ability to deactivate ROS stems from mechanisms such as triplet–triplet energy transfer, electron transfer, hydrogen atom donation, and radical adduct formation (Karpioski et al., 2022). Furthermore, carotenoids' antioxidant activity is directly proportional to the number of conjugated double bonds in their structure (Zakynthinos & Varzakas, 2016).

In addition to antioxidant capacity, carotenoids exhibit anti-inflammatory and antimicrobial activities. They interact with the NF-κB pathway, inhibiting its nuclear translocation and consequently reducing the expression of inflammatory cytokines such as interleukin-8 and prostaglandin E2 (Kaulmann & Bohn, 2014). Moreover, carotenoids have been reported to interfere with efflux pump activity in bacteria by disrupting ATP hydrolysis, altering membrane permeability, and increasing intracellular ROS production, thereby exerting antibacterial effects (Zakynthinos & Varzakas, 2016).

Carotenoids also contribute to cancer prevention by modulating signaling pathways associated with apoptosis, cell cycle arrest, and metastasis. Their chemopreventive roles include inhibition of tumor cell proliferation and enhancement of programmed cell death (Niranjana et al., 2015).

Numerous studies have explored the fortification of fermented dairy products with carotenoid-rich sources to enhance their functional properties. Kiros et al. (2016) reported that yogurt fortified with carrot or carrot oil demonstrated significantly higher carotenoid content and antioxidant activity compared to the control. Specifically, the addition of carrot oil resulted in a carotenoid concentration of 10.26 mg/kg in fresh yogurt. Similarly, a study by Balabanova et al. (2020) evaluated the impact of incorporating different pepper varieties into yogurt. Among them, yogurt enriched with *Kurtovska Kapia* showed the highest carotenoid content (570.02 µg/100g), exceeding the levels found with other varieties such as *Doux Marconi Geonet* and *Balgarian Ratunt*.

These findings highlight the potential of carotenoid fortification in enhancing the health-promoting properties of dairy products, making them valuable functional foods in modern diets.

Dietary Fiber

Dietary fiber refers to the indigestible portion of plant-derived carbohydrates, primarily in the form of polysaccharides, that escapes enzymatic digestion in the human small intestine. These fibers are broadly classified based on their water solubility into two major types: soluble and insoluble fibers. Soluble dietary fibers include pectin, gums, mucilage, fructans, and specific types of resistant starches, which are commonly found in fruits, vegetables, oats, and barley. In contrast, insoluble fibers such as lignin, cellulose, and hemicellulose are mainly sourced from whole grains, nuts, seeds, and vegetables (Soliman, 2019).

The inclusion of dietary fiber in daily intake has been associated with a reduction in the risk and severity of a range of health disorders, including constipation, diverticulosis, colorectal cancer, type 2 diabetes, obesity, cardiovascular diseases, and gallstones. Moreover, increased fiber intake has been linked to a reduction in serum cholesterol and blood pressure levels (Li & Komarek, 2017).

An increasing body of research has focused on the enrichment of dairy products with plant-derived dietary fiber sources. Issar, Sharma, and Gupta (2017) reported that the incorporation of 5% apple pomace fiber into acidophilus yogurt resulted in an acceptable sensory profile and enhanced fiber content, making it a suitable approach for

developing fiber-enriched fermented dairy products. Similarly, Kurt and Atalar (2018) demonstrated that the addition of quince seed-derived dietary fibers significantly increased the viscosity of yogurt, from 0.266 to 0.317 Pa·s, potentially improving the textural attributes and functional value of the product.

Fatty Acids

Fatty acids (FAs) are fundamental lipid components classified based on their saturation level. Saturated fatty acids (SFAs), such as palmitic acid (C16:0), stearic acid (C18:0), myristic acid (C14:0), and lauric acid (C12:0), are characterized by the absence of double bonds in their hydrocarbon chains. Unsaturated fatty acids (UFAs), which include monounsaturated (MUFAs) and polyunsaturated fatty acids (PUFAs), are distinguished by the presence of one or more double bonds (Karaguzel et al., 2019). Notably, oleic acid (C18:1), linoleic acid (LA, C18:2, omega-6), and alpha-linolenic acid (ALA, C18:3, omega-3) are the predominant UFAs found in plant sources.

PUFAs, particularly omega-3 fatty acids like ALA, eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA), are recognized for their beneficial effects in preventing cardiovascular diseases, modulating inflammation, and supporting neurological development (Dal Bello et al., 2017). Conversely, a disproportionate intake of omega-6 PUFAs, especially in the absence of adequate omega-3s, has been associated with adverse health outcomes (Shrestha et al., 2020).

In recent years, extensive research has focused on the fortification of dairy products with plant-derived oils rich in essential fatty acids. Ozturkoglu-Budak et al. (2016) observed that yogurt enriched with walnuts exhibited a significant increase in total fatty acid content (69.54 g/100 g) compared to variants fortified with hazelnuts, almonds, or pistachios. This enhancement was attributed to the high EPA and DHA content in walnuts, which also contributed to lower stiffness development during storage.

Similarly, Van Nieuwenhove et al. (2019a) demonstrated that yogurt fortified with pomegranate seed powder exhibited a 1.8-fold increase in conjugated linolenic acid (CLnA) compared to yogurt fortified with Jacaranda seed. The addition of these plant powders did not adversely affect the pH or sensory properties of the yogurts, even after 28 days of storage (Van Nieuwenhove et al., 2019b).

Dal Bello et al. (2017) reported that cheese samples fortified with blackcurrant oil presented the highest omega-6 PUFA levels (12.21 mg/g) on day one, surpassing samples fortified with raspberry, flaxseed, camelina sativa, and echium oils. The greatest omega-3 content (4.43 mg/g) was recorded in cheeses fortified with camelina oil. Interestingly, flaxseed oil-fortified cheeses exhibited a significant decrease in omega-3 content after three days of ripening. No significant differences were found in protein, moisture, ash content, or pH among control and fortified cheeses. Among the oil treatments, the combinations of flaxseed and raspberry oils were found to be the most favorable in terms of fatty acid composition and consumer acceptance.

Table 01 - Natural sources rich in bioactive compoubds

Natural Source	Examples	Phenolic Compund	Reference
Herbs	Red ginseng	Polyphenols	(H. Park et al., 2018)
	Sea buckthorn	Carotenoids	(Ghendov-Moşanu et al., 2020)
Spices	Turmeric	Carotenoids	Hasneen et al., 2020)
	Ginger	Phenolics	(Ahmed et al., 2021a)
	Dried curry leaves	Phenolics	(Weragama et al., 2021)
	Pepper	Carotenoids	(Balabanova et al., 2020)
	Cinnamon	Phenolics	(Vidanagamage et al., 2016)
	Strawberry	Phenolics	(Jaster et al., 2018)
	Passion	Phenolics	(Ning et al., 2021)
	Pomegranate	Phenolics	(Van Nieuwenhove et al., 2019b)
	Mango	Carotenoids	(Vicenssuto & de Castro, 2020a)
Vegetables	Carrot	Carotenoids	(Kiros et al., 2016)
	Spinach	Phenolics	(Göksel Saraç & Dogan, 2016)
Nuts and oil crops	Walnut	Fatty acids	(Ozturkoglu-Budak et al., 2016)
	Hazelnut	Fatty acids	(Ozturkoglu-Budak et al., 2016)
	Almond	Fatty acids	
Cereals	Black rice	Phenolics	(Khalil & Elkot, 2020)
	Wheat	Phenolics	(Çetinkaya & Öz, 2020)

Bioactive Compounds in Fermented Dairy Products

Fermented dairy products are rich sources of bioactive compounds, primarily produced through the metabolic activity of microorganisms such as lactic acid bacteria (LAB), yeasts, and molds. These microorganisms contribute to the synthesis of several functional metabolites, including exopolysaccharides (EPS), conjugated linoleic acid

(CLA), bioactive peptides, gamma-aminobutyric acid (GABA), galactooligosaccharides (GOS), and essential vitamins (Linares et al., 2017).

The vitamin profile of fermented dairy products is notably enhanced, especially in riboflavin and vitamin B12, which are synthesized during fermentation by specific strains of LAB. The consumption of such fortified products may contribute to reducing vitamin deficiencies in human populations (Savaiano & Levitt, 1984). Moreover, GABA is synthesized through the decarboxylation of glutamic acid by LAB and plays a vital role in human neurological function, contributing to the regulation of neurotransmission and stress responses (Santos-Espinosa et al., 2020).

Exopolysaccharides, also produced by starter cultures, are recognized for their dual functionality: enhancing textural attributes of fermented dairy products and promoting gut health by acting as prebiotic-like agents (Santos-Espinosa et al., 2020). In addition, bioactive peptides, typically composed of 2 to 20 amino acids, are generated via the proteolytic activities of microbial enzymes during fermentation. These peptides exert multiple physiological benefits, including antihypertensive, antioxidant, immunomodulatory, and antimicrobial effects, making them crucial targets in functional food research (Y. W. Park & Nam, 2015).

CLA, another key metabolite, exhibits strong antioxidant activity and is implicated in reducing the risk of chronic conditions such as cardiovascular disease, obesity, and certain cancers. Its inclusion in fermented dairy further enhances the health-promoting properties of these products, thereby supporting their role in maintaining a healthy lifestyle (Y. W. Park & Nam, 2015).

Collectively, these microbial-derived bioactive compounds not only improve the nutritional and functional quality of fermented dairy products but also underscore their potential in the prevention and management of various health disorders. This has spurred considerable scientific interest in optimizing fermentation conditions and microbial strains to enhance the bioavailability and efficacy of these compounds in functional dairy foods.

Natural sources of bioactive compounds used in fermented dairy products.

Health effect of fortification of fermented dairy products with bioactive rich natural compounds

Table 02a - quantitative evaluation of the effects of the bioactive compounds.

Dairy product	Natural Additive	Major bioactive ingredients	Experimental findings	Reference
Set yoghurt	Passion fruit juice (PFJ)	polyphenols	Total phenolic content (µg GAE/g) of set yoghurt increased from 1.69 to 11.4 with the addition of 2.5% PFJ. The antioxidant effect increased from 2.75% to 35.8% PFJ. (DPPH)	(Ning et al., 2021)
yoghurt	Red ginseng extract(RGE)	Polyphenols (ginseng saponins) Flavonoids	Total phenolic content (mg of GAE/100 g) and total flavonoid content (mg of GAE/100 g) of yogurt increased from 8.1 to 41.1 and from 8.4 to 18.7 with the addition of 2% red ginseng extract respectively. The antioxidant effect (µg/mL) of yoghurt increased from 5.8 - 13.1 to 18.7 - 41.1 with the addition of 2% red ginseng extract. (DPPH RSA)	(Park et al., 2018)
Probiotic yogurt	Green, black and white tea	Polyphenols	The highest total phenolic content (mg GAE/ml) recorded in green tea yoghurt (526.34). There was a significant reduction in TPC of all tea enriched yoghurts during storage. ($p<0.05$) The antioxidant activity of plain yoghurt (3-7%) increased into 83-97% with the addition of tea extracts ($p<0.05$)	(Muniandy et al., 2016)
yoghurt	Pomegranate seed (PS) and jacaranda seed (JS)	Fatty acids (conjugated linolenic acid) (CLnAS)	CLnAS of PS (62-63mg/100g) increased by 1.8-fold compare to JS yogurt. Highest antioxidant activity recorded in PS (61.55%). There was significantly decrease in antioxidant effect during 28 days.	(Van Nieuwenhove et al., 2019)

Table 02b - quantitative evaluation of the effects of the bioactive compounds.

Yoghurt	Walnut Hazelnut Almond Pistachio	Vitamins(folic acids, tocopherols) Minerals (selenium) Fatty acids	Highest folic acid amount (29.29 µg/100g) and fatty acid amount (69.54%) recorded in walnut enriched yoghurt. Highest Selenium (2.65 µg/100g) and ϒ-tocopherol (1.94 mg/100g) recorded in pistachio enriched yoghurt. Highest α-tocopherol content recorded in hazelnut enriched yoghurt (4.87 mg/100g). Almond enriched yoghurt had high protein (5.91wt/wt%) and walnut enriched yoghurt had high fat content(6.10wt/wt%). Lowest count of streptococci and L. *bulgaricus* recorded in walnut enriched yogurt.	(Ozturkoglu-Budak et al., 2016)
Dahi (Indian yoghurt)	Flax seed oi microcapsules	Fatty acids(α-linolenic acid)	A- linolenic acid (ALA) increased up to 10.62% with addition of 2% micro encapsulated flaxseed oil powder. ALA reduced (8.40) continuously during 15 days.	(Goyal et al., 2016)
Yoghurt	Carrot waste extract (CW)	Carotenoids	The highest beta-carotene bleaching antioxidant capacity(9.36 µmolTE/180g), reducing power(3.11 µmolTE/180g) recorded with 5CW beads enriched yoghurt. Highest antihyperglycemic activity(13.91%) and anti-inflammatory activity(15.27%) recorded with 5CW beads enriched yoghurt.	(Šeregelj et al., 2021)
Yoghurt	Seaweeds varieties (*Aacophyllum nodosum, fucus vesiculosus*)	Phenolics	Seaweed enriched yoghurts didn't exhibit cellular antioxidant activity.	(O'Sullivan et al., 2016)
Soft cheese	Clove Thyme Ginger	Phenolics (thymol, eugenol)	The minimum inhibitory concentration of clove, thyme and ginger essential oils was 0.001% for *S. aureas, E.coli, Ent. faecalis, P.aeruginosa, P.fluorascens, C. albicans, A. parasiticus* .	
Cream cheese	Dried curry leaves (DCL)	Phenolics	The highest phenolic content (193.33 mg GAE/100g) and highest antioxidant effect (lowest value of 0.06 IC_{50} (mg/ml) recorded with 0.25% DCL addition. Moisture and total solid content didn't significantly affect with DCL addition. Highest FRAP value (0.17Mm Fe(Ⅱ) was recorded with 0.25% DCL addition. Lowest fat level (33.01%) recorded with 0.25% DCL addition.	(Weragama et al., 2021)
Soft cheese	*Arbutus unedo L.* (AUL)	Phenolics Dietary fiber	Highest antioxidant effect recorded with 1g/L AUL extract and it decreased during 5days of storage period. (DPPH method) Fat and ash didn't significantly affect by AUL addition. Protein (46%) significantly increased by 1g/L AUL addition.	(Masmoudi et al., 2020)

Table 02b - quantitative evaluation of the effects of the bioactive compounds.

Processed cheese spread	Black rice powder(BRP)	Crude fiber phenolics	Highest total phenolic content (44.23 mg GAE/g) recorded by 6% BRP addition and it was reduced (36.62 mg GAE/g) gradually during 90days storage. Highest antioxidant scavenging activity 64.82% recorded 6% BRP addition and it was reduced (54.97) gradually during 90days storage. Dry matter and far were not significantly differed due to BRP addition. Protein (9.42%) was reduced by 6% BRP addition. Noticeable antimicrobial effect didn't recorded with BRP addition.	(Khalil & Elkot, 2020)
Labneh cheese	Pepper varieties Doux Marconi geonet, balgarian ratunt, kurtovska kapia, Doux Marconi geonet x kurtovska kapia, Doux	Phenolics Carotenoids Chlorophyll	The highest carotenoids (570.02 µg/100g), chlorophylls (960.29 µg/100g), total phenols (34.24GAE/100g), total flavonoids (0.05mg QE/100g) and antioxidant effect (28.95 Mm TE/100g) recorded with addition of kurtovska kapia variety. A slight decrease in phenols and flavonoids observed during storage. A significant difference for moisture, fat, total protein didn't recorded with addition of pepper.	(Balabanova et al., 2020)
Cream cheese	Sea buckthorn lipophilic extracts(SBLE)	Carotenoids polyphenols	28.89% antiradical activity recorded with addition of 2.5% SBLE. 11.95% fat level recorded with 2.5% SBLE addition. Total viable count(CFU/g)*2 reduced from 54 to 10 with 2.5% SBLE addition after 10 days storage.	(Ghendov-Moşanu et al., 2020)
Fresh cheese	Flaxseed oil(FS) *Camelina sativa* oil(CAM) Raspberry(RAS) *Echium plantagineum* oil(EC) Blackcurrent oil(BC)	Fatty acids(omega-3 FA and omega-6 FA)	Highest omega-6 FA (12.21mg/g) recorded with addition of BC oil. Highest omega-3 FA (4.43 mg/g) recorded with addition of CAM oil. Omega-3 FA (α-linolenic acid) in FS enriched cheese showed a significance difference during storage.($p<0.01$) Protein, moisture and ash didn't significantly differ with vegetable oil addition. Fat content increased (23.00%w/w) with the addition of RAS oil. Antimicrobial effect didn't show a significant difference among cheese samples.	(Dal Bello et al., 2017)
White cheese	Wheat germ (WG)	Fatty acids	High amount of poly unsaturated fatty (PUFA)acids and saturated fatty acids (SFA) recorded with 2% WG addition. SFA and PUFA increased significantly during 30 days storage.($p<0.05$) Highest percentage of fat (13.93), protein (18.09), dry matter(42.03) and salt(3.85) recorded with 2% WG addition. fat, protein, dry matter and salt content increased significantly during storage ($p<0.05$, $p<0.01$)	(Çetinkaya & Öz, 2020)
Butter	Olive pomace (OP) Olive mill waste water (OMWW)	Phenolics	Total mesophilic aerobic flora of butters enriched with 8mg of OMWW and 8mg of OP showed zero level. Antibacterial and antifungal effects showed with OMWW and OP addition for total coliforms, yeast and moulds and *Staphylococcus aureus*	(Mikdame et al., 2020)

Table 02c - quantitative evaluation of the effects of the bioactive compounds.

Butter	Cinnamon Extract(CE)	phenolics	Total phenolic content(µg GAE/mg) of 135.62 and antioxidant activity of 38.73% recorded in cinnamon enriched butter. Crude fat (82.12%), protein (0.76%), moisture (14.65%), CHO (0.08%), ash (2.39%) recorded with CE addition. Yeast and moulds weren't in cinnamon enriched yoghurt throughout the storage. Highest antimicrobial activity recorded in cinnamon enriched butter. (total plate count of $1.63*10^2$ CFU/g at 8th week).	(Vidanagamage et al., 2016)
Fermented milk	Pomegranate peel extract(PPE)	Phenolics	Significantly high total phenolic content and antioxidant activity recorded in fermented milk with PPE addition. The concentration below the 2% w/v didn't show an antimicrobial effect against *L. acidophilus*	(Chan et al., 2018)
Fermented milk	Grape marc (GM) Olive pomace (OP)	Phenolics	Highest total phenolics(98.5 µg GAE/g) level recorded with OP addition and it decreased by 28% during 50days storage.($p<0.05$) Highest antiradical power (ARP) (72.75%) recorded with OP addition and longer storage wasn't affected significantly on quantity of ARP. *S. thermophilus* count decreased not (statistically significant) during 14 days and the count was similar to control sample after 14 days *L. acidophilus* remained constant.	(Aliakbarian et al., 2015)
Kefir	Black mulberry juice(BMJ) Pomegranate juice(PJ) Strawberry juice(SJ) Black carrot juice(BCJ)	Phenolics (Anthocyanin)	Highest anthocyanin content(404.5 mg/L) and stability(32.1 weeks) recorded with 25% of BMJ addition. Antioxidant effects increased with 25% (1.8-4.8 times) compare to the plain kefir. Highest with BCJ addition-6.39). Highest antioxidant activity(6.39 mM Trolox/ml) recorded with 25% BCJ addition. Most decreased lactobacillus count showed in PJ 10% and 25% and SJ 25%. Lowest Lactococcus count recorded in PJ 25%.	(Kabakcı et al., 2020)
Kefir	Mango peel(MP)	Phenolics	21.35% increased antioxidant activity recorded in mango peel enriches kefir compared to the control kefir. Antioxidant activity increased 113%(13.81 µmol TE/g) compare the control by addition of MP.(DPPH RSA method) effect on antimicrobial effect against acidic bacteria and yeast.	(Vicenssuto & de Castro, 2020)

Commonly Found Effects of Bioactive Compounds

Antioxidant Effect

The antioxidant effect refers to the ability of a compound to mitigate or prevent the formation of oxidizable substances during metabolism, thereby minimizing damage to the body (Brainina et al., 2019). Oxidation is primarily driven by reactive oxygen species (ROS) such as superoxide ions, singlet oxygen, lipid peroxides, and hydroxyl radicals. Antioxidants, which are abundant in fruits and vegetables, play a key role in reducing oxidative stress caused by these ROS (Serafini & Peluso, 2016).

Bioactive compounds derived from natural sources act by converting ROS into non-radical species, disrupting autoxidative chain reactions, and lowering local oxygen concentrations (Hunyadi, 2019). Oxidative stress is a contributing factor to various chronic diseases including cancer, cardiovascular diseases, diabetes, age-related muscular degeneration, and ocular disorders.

In fermented dairy products, the DPPH Radical Scavenging Activity (RSA) method is commonly employed to assess antioxidant activity. DPPH, a purple-colored radical, becomes colorless upon receiving electrons from antioxidants. Other analytical methods used include ABTS, FRAP, and FIC assays. Natural antioxidants include phenolic compounds, carotenoids, and vitamins, which not only contribute to health benefits but also improve product shelf-life and quality (Wilson et al., 2017).

For example, Masmoudi et al. (2020) reported increased antioxidant activity in products supplemented with 30% spirulina powder (SP), with DPPH RSA and ABTS values reaching 9.19 mg GAE/mL and 0.38 mg GAE/mL, respectively. Muniandy (2016) found that green tea-enriched yogurt showed the highest antioxidant activity according to DPPH RSA and FRAP methods, while black tea-enriched yogurt performed best in the FIC method. This suggests that DPPH RSA and FRAP assess primary antioxidant activity, while FIC evaluates secondary antioxidant activity. However, antioxidant activity tends to decline during storage due to phenolic degradation.

Antimicrobial Effect

Microorganisms in food can alter its color, texture, odor, flavor, and safety. Bioactive compounds, especially phenolics, possess antimicrobial properties against both Gram-negative and Gram-positive bacteria due to the presence of functional groups like hydroxyls (Khameneh et al., 2019). These compounds are found naturally in herbs, spices, fruits, vegetables, seeds, and leaves.

Phenolic compounds such as eugenol, thymol, carvacrol, vanillin, allicin, cinnamic aldehydes, and allyl isothiocyanate contribute significantly to the antimicrobial properties of herbs and spices (Ghendov-Moşanu et al., 2020; Ozturkoglu-Budak et al., 2016). Fatty acids and dietary fibers also play supporting roles (Khalil & Elkot, 2020; Mehdizadeh et al., 2019).

The mechanisms of antimicrobial activity include membrane disruption, pH reduction, and enzymatic inhibition. Microbial testing often targets yeasts, molds, coliforms, Streptococcus species, and psychrotrophs (Enab et al., 2012). A study by Ozturkoglu-Budak et al. (2016) found a positive correlation between plant-based fortification and antioxidant activity. Additionally, walnut-enriched yogurt showed the lowest counts of *Streptococcus* and *L. bulgaricus*.

Anti-Hyperglycemic Properties

Diabetes is one of the most prevalent non-communicable diseases globally. Bioactive compounds from natural sources like fruits, vegetables, herbs, and grains can lower blood glucose levels (Vinayagam et al., 2016). Phenolics are particularly effective, as they reduce insulin resistance, promote glucose uptake, increase glycogen synthesis, and inhibit carbohydrate-digesting enzymes such as α-glucosidase and α-amylase.

The efficacy of these compounds is often evaluated using α-glucosidase inhibition assays. Bioactives affect multiple organs, including the liver, pancreas, intestine, muscle, and adipose tissue. Šeregelj et al. (2021b) demonstrated that plant-based fortification correlates positively with anti-hyperglycemic activity. Kiros et al. (2016) found improved glycemic control in carrot juice-enriched products.

Anticarcinogenic Effect

Dietary habits play a significant role in the prevention of chronic illnesses, including various types of cancer. Epidemiological studies have linked high fruit, vegetable, and grain intake with reduced risks of heart disease, cancer, diabetes, Alzheimer's, and age-related decline (Subramaniam et al., 2019). The National Cancer Institute has recognized approximately 35 plant-based foods with potential anti-cancer properties, including garlic, soybeans, ginger, licorice root, and cruciferous vegetables such as broccoli and cabbage.

Oxidative stress, which damages macromolecules like DNA, proteins, and lipids, contributes to carcinogenesis and cardiovascular disease. Antioxidants, particularly phenolics and carotenoids from plants, mitigate this damage (Chandra et al., 2012). Rosemary, due to its phenolic hydroxyl groups, is a strong candidate for chemoprevention. Its bioactive compounds exhibit antimicrobial, antiviral, anti-inflammatory, and anticarcinogenic properties (Sereiti et al., 1999; Aherne et al., 2007; Moore et al., 2016).

Limitations

Extraction Method

Traditional extraction methods such as hydroalcoholic distillation, Soxhlet extraction, and maceration are commonly used to extract bioactive compounds. These methods often require high solvent volumes and long extraction times. In hydro distillation, high temperatures can degrade heat-sensitive compounds, potentially leading to inaccurate estimations (Ahmed et al., 2021b; Qiu et al., 2021; Ribeiro et al., 2016).

Soxhlet extraction, developed by Franz Rizz Von Soxhlet, uses solvents to extract oils and other bioactives but also exposes compounds to heat, risking degradation (Sasidharan et al., 2011). Maceration, on the other hand, avoids heat and better preserves thermolabile compounds, though it still demands considerable time and results in crude extracts that require further purification.

Emerging methods like enzyme-assisted extraction, supercritical fluid extraction, pressurized liquid extraction, ultrasound-assisted extraction, microwave-assisted extraction, and pulsed electric field extraction offer advantages in efficiency and selectivity but are cost-prohibitive for many research applications (Azmir et al., 2013).

Storage Effect

Storage is a critical factor in evaluating the effectiveness of bioactive compounds in fortified fermented dairy products. Over time, the efficacy of these compounds may diminish due to degradation or complex formation with milk proteins (Josipovid et al., 2015; Ozturkoglu-Budak et al., 2016). However, some studies have shown increased bioactivity post-storage, attributed to microbial breakdown and subsequent release of phenolics (Vicenssuto & de Castro, 2020a). Stabilization methods such as microencapsulation are being explored to preserve bioactivity during storage (Aramrueang et al., 2019).

Methodology of Investigation

The DPPH Radical Scavenging Assay is the most widely used method to assess antioxidant activity. In this assay, the purple DPPH radical is reduced to a colorless product by antioxidant compounds, typically measured at 515–528 nm. Additional techniques include the ABTS assay, Ferric Reducing Antioxidant Power (FRAP), and Ferric Ion Chelating (FIC) methods. Each method evaluates different aspects of antioxidant capacity, ranging from electron donation (DPPH, FRAP) to metal ion chelation (FIC), providing a comprehensive understanding of antioxidant potential

Conclusion

This review aimed to evaluate the effects of bioactive plant compounds on fermented dairy products. The findings highlight the significant potential of incorporating these compounds into products such as yogurt and cheese, which are widely consumed and therefore ideal vehicles for nutritional enhancement. Among the various sources, spices and fruits emerged as the most commonly used natural carriers of bioactive compounds, largely due to their favorable sensory properties. Furthermore, the antioxidant effects of these compounds have been extensively investigated, attributed to the high phenolic content present in many plant sources. Future research could focus on elucidating the specific interactions between bioactive compounds and fermented dairy matrices, which would help to better differentiate their functional and sensory effects.

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The Role of Zinc Supplementation in Reducing Oxidative Stress via Histone Modifications in Heat-Stressed Broiler Chickens

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Abstract

Heat stress (HS) significantly impacts the welfare of broiler chickens, which play a vital role in the global meat industry. The effects of heat stress on the colon of chickens are not yet fully understood. This study aimed to determine whether the inclusion of zinc in the diet of heat-stressed broilers could enhance their ability to manage with heat stress. Specifically, we investigated the impact of organic zinc supplementation on colon histology and the expression of heat stress-related genes in broiler chickens. A total of 1024 Xueshan chickens were assigned to four experimental groups: control, heat stress (HS), 90 mg/kg zinc, and HS with 90 mg/kg zinc. The results demonstrated that zinc intake significantly improved villus height (VH) and the VH:crypt depth (CD) ratio in the colon compared to the HS group, while a decrease in crypt depth and villus width was observed in both zinc-supplemented groups. Additionally, zinc administration led to higher levels of GSH, CAT, and SOD along with reductions in MDA and ROS compared to the HS group. It also significantly enhanced the relative ATP levels and enzymatic activities of complexes I, III, and V as compared to the HS condition. Furthermore, the protein expression of TFRC, ACSL4, PRX, and LPCAT3 were notably reduced in the HS+Zn group relative to the HS group. Zinc intake also decreased the enrichment of transcriptional regulators SRC1, P300, and RORγ at the promoter regions of PRX, LPCAT3, and ACSL4. A significant reduction in histone active marks, including H3K27ac and H3K9ac were observed at the loci of LPCAT3 and ACSL4 in the HS+Zn group compared to the HS group. This research highlights the potential of organic zinc as a strategy for modulating the oxidative genes TFRC, ACSL4, PRX, and LPCAT3 in the colon of chickens through the regulation of nuclear receptor RORγ and histone modifications.

Key words: *Oxidative stress; histone modification; colon; zinc; broiler chicken*

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The Place of Animal Production in the Agricultural Sector: Economic Contributions and Future Perspectives

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Abstract

This study examines the place of animal production in the agricultural sector in Türkiye, its economic contributions and its potential for the future in a multifaceted manner. According to the research findings, the share of the agricultural sector in Türkiye's 1,118.25 billion dollars of GDP in 2023 will be approximately 6%, while the share of animal production in agricultural production will be around 35%. This rate remains below the 45% level in the European Union countries, offering significant potential that can be developed. In the study, data for the period 2018-2024 were analyzed, and fluctuations in the number of large and small cattle were detected. After the increasing trend in large cattle between 2018-2021, a decrease was observed and a partial recovery was observed in 2024, while in the number of small cattle, a decrease was observed after the peak in 2021 and a tendency to increase again in 2024. In poultry farming, especially in 2024, there was a 22% increase in meat chicken production, while there was a significant decrease of 15.5% in the number of egg chickens. As a result of the research, it is recommended that feed costs be reduced for the sustainable development of Türkiye's animal production sector, the productivity of local breeds be increased, systems to adapt to climate change be developed, the organization of small and medium-sized producers be supported, digital technologies be disseminated and value-added production be focused on. It is emphasized that long-term and predictable support policies should be implemented, holistic strategies should be developed to increase the share of animal production in the agricultural economy and bring it closer to EU standards.

Key Words: *Agricultural Production, Animal Production, Rural Development, Sustainable Agriculture*

Tarım Sektöründe Hayvansal Üretimin Yeri: Ekonomik Katkılar ve Geleceğe Yönelik Perspektifler

Özet

Bu çalışma, Türkiye'deki hayvansal üretimin tarım sektöründeki yerini, ekonomik katkılarını ve geleceğe yönelik potansiyelini çok yönlü olarak incelemektedir. Araştırma bulgularına göre, 2023 yılında Türkiye'nin 1.118,25 milyar dolarlık GSYİH'si içerisinde tarım sektörünün payı yaklaşık %6 olup, tarımsal üretimin içinde hayvansal üretimin payı %35 civarındadır. Bu oran, Avrupa Birliği ülkelerindeki %45 düzeyinin altında kalarak geliştirilebilecek önemli bir potansiyel sunmaktadır. Çalışmada 2018-2024 dönemi verileri analiz edilmiş, büyükbaş ve küçükbaş hayvan varlığında dalgalanmalar tespit edilmiştir. Büyükbaş hayvancılıkta 2018-2021 arası görülen artış eğiliminin ardından düşüş ve 2024'te kısmi toparlanma, küçükbaş hayvan varlığında ise 2021'deki zirvenin ardından düşüş ve 2024'te yeniden artış eğilimi gözlenmiştir. Kümes hayvancılığında özellikle 2024'te et tavuğu üretiminde %22'lik artış kaydedilirken, yumurta tavuğu sayısında %15,5'lik ciddi bir düşüş yaşanmıştır.
Araştırma sonucunda, Türkiye'nin hayvansal üretim sektörünün sürdürülebilir gelişimi için yem maliyetlerinin düşürülmesi, yerli ırkların verimliliklerinin artırılması, iklim değişikliğine uyum sağlayacak sistemlerin geliştirilmesi, küçük ve orta ölçekli üreticilerin örgütlenmesinin desteklenmesi, dijital teknolojilerin yaygınlaştırılması ve katma değerli üretime odaklanılması önerilmektedir. Uzun vadeli ve öngörülebilir destekleme politikalarının uygulanması, hayvansal üretimin tarımsal ekonomideki payının artırılması ve AB standartlarına yaklaştırılması için bütüncül stratejilerin geliştirilmesi gerektiği vurgulanmaktadır.

Anahtar Kelimeler: *Tarımsal Üretim, Hayvansal Üretim, Kırsal Kalkınma, Sürdürülebilir Tarım*

Giriş

Tarım sektörü, toplumların ekonomik, sosyal ve çevresel kalkınmasında temel bir rol üstlenmektedir. Bu sektör, yalnızca bitkisel üretimi değil, aynı zamanda hayvansal üretimi de kapsayarak geniş bir üretim yapısını içinde barındırmaktadır. Özellikle hayvansal üretim, hem gıda güvenliği hem de beslenme kalitesi açısından kritik öneme sahiptir. Hayvansal ürünler, temel protein, vitamin ve mineral kaynağı olmalarının yanı sıra, ekonomik anlamda

da istihdam ve gelir yaratma potansiyeliyle dikkat çekmektedir (FAO, 2023). Ayrıca hayvansal üretim, tarımsal üretimin sürekliliğini sağlamada ve kırsal nüfusun geçim kaynaklarını çeşitlendirmede kilit bir rol oynamaktadır. Bu yönüyle sektör, hem bireysel refahın artırılmasına hem de makro düzeyde ekonomik büyümeye katkı sunmaktadır.

Hayvansal üretim, sadece kırsal bölgelerde değil, şehirleşmeyle birlikte artan hayvansal gıda talebi nedeniyle ulusal düzeyde stratejik öncelik taşıyan bir alan haline gelmiştir. Et, süt, yumurta gibi hayvansal ürünler; bireylerin sağlıklı beslenmesini sağlamasının ötesinde, ihracat kalemleri arasında yer alarak ülke ekonomisine doğrudan katkı sunmaktadır (OECD, 2022a). Ayrıca hayvancılık faaliyetleri, yem bitkileri üretimi, veteriner hizmetleri, lojistik ve gıda işleme gibi birçok alt sektörle güçlü bir ilişki içerisinde olup, ekonomik çarpan etkisi yaratmaktadır (Turan, 2024).

Bununla birlikte, hayvansal üretimin önemi yalnızca ekonomik katkılarla sınırlı değildir. Kırsal kalkınmanın sağlanmasında, tarımsal üretimin çeşitlendirilmesinde ve kırsalda göçün önlenmesinde de önemli bir rol üstlenmektedir. Özellikle küçük ölçekli işletmeler için hayvancılık, sürekli gelir sağlayan bir faaliyet alanı olması bakımından sosyal sürdürülebilirliğin anahtarıdır (Demir vd., 2016). Bu yönüyle hayvansal üretim, sadece ekonomik değil, aynı zamanda sosyo-kültürel bir işlev de görmektedir. Hayvancılık faaliyetleri, kadınların ve gençlerin üretim sürecine aktif katılımını destekleyerek toplumsal cinsiyet eşitliği ve kuşaklar arası işbirliği açısından da olumlu etkiler yaratmaktadır. Ayrıca, geleneksel hayvancılık kültürünün korunması, kırsal kimliğin yaşatılması ve yerel festivaller gibi kültürel etkinliklerin sürdürülmesinde de belirleyici rol oynamaktadır.

Ancak, iklim değişikliği, yem maliyetlerindeki artış, arazi kullanımı baskıları ve hayvancılığın çevresel etkileri gibi küresel ve yerel düzeyde yaşanan bazı sorunlar, hayvansal üretimin sürdürülebilirliğini tehdit etmektedir (Steinfeld vd., 2006). Bu durum, hayvansal üretimin geleceğini yeniden düşünmeyi ve politika yapıcıların sektöre yönelik uzun vadeli stratejiler geliştirmesini zorunlu kılmaktadır. Aynı zamanda yeni teknolojilerin, verimlilik artırıcı yöntemlerin ve çevre dostu uygulamaların entegrasyonu, sektörün dönüşüm sürecinde kilit rol oynamaktadır (Karaman, 2018).

Bu çalışma, tarım sektörünün önemli bir alt bileşeni olan hayvansal üretimin mevcut yerini, ekonomik katkılarını ve geleceğe yönelik potansiyelini çok yönlü olarak ele almayı amaçlamaktadır. Çalışma kapsamında, hayvansal üretimin tarımsal ekonomi içerisindeki stratejik rolü değerlendirilerek, hem ulusal hem de küresel gelişmeler ışığında sektörün güçlü ve zayıf yönleri analiz edilecektir. Böylece hem akademik literatüre katkı sunmak hem de sektörel gelişim için politika yapıcılara yol gösterici öneriler geliştirmek hedeflenmektedir.

Materyal ve Yöntem

Bu çalışmada, Türkiye'deki hayvansal üretimin tarım sektöründeki yeri, ekonomik katkıları ve geleceğe yönelik perspektiflerinin analizi için ikincil veri kaynakları kullanılmıştır. Araştırmanın temel veri kaynakları Dünya Bankası (World Bank), Birleşmiş Milletler Gıda ve Tarım Örgütü (FAO) ve Türkiye İstatistik Kurumu (TÜİK) tarafından sağlanan resmi istatistiklerden oluşmaktadır.

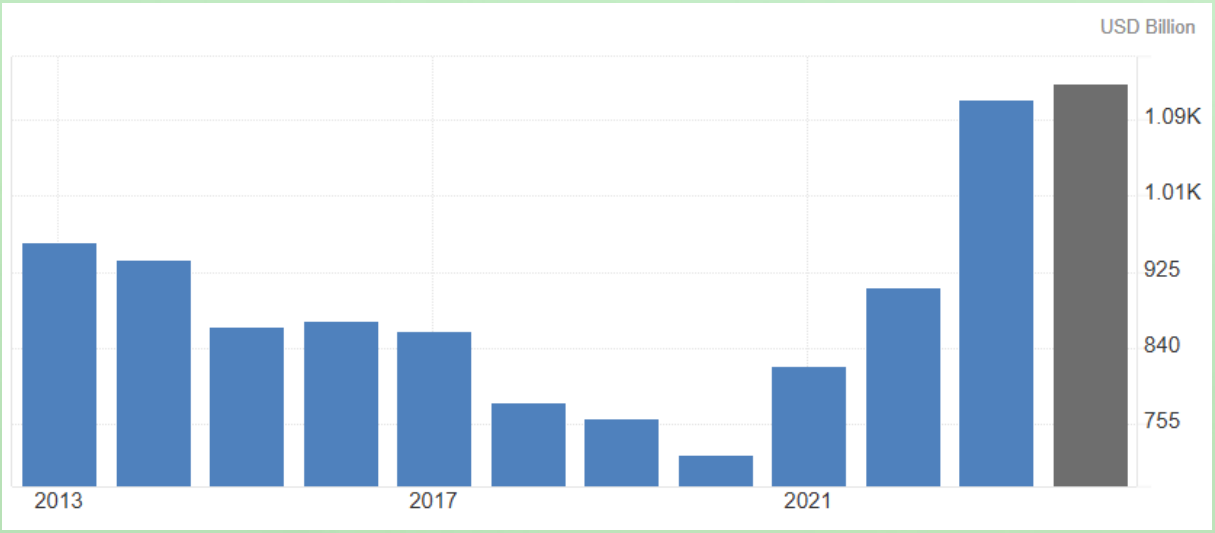
Araştırma kapsamında, söz konusu kurumların veri tabanlarından elde edilen zaman serisi verileri değerlendirilmiş ve analiz edilmiştir. Çalışmada büyükbaş hayvan varlığı (sığır, manda), küçükbaş hayvan varlığı (koyun, keçi) ve kümes hayvancılığı (et tavuğu, yumurta tavuğu, hindi, kaz, ördek) verilerini içeren kapsamlı bir hayvansal üretim analizi gerçekleştirilmiştir.

Metodolojik açıdan çalışmada, elde edilen verilerin betimsel analizi yapılmış ve zaman içerisindeki değişim eğilimleri değerlendirilmiştir. Büyükbaş, küçükbaş ve kanatlı hayvan varlığının yıllara göre gösterdiği dalgalanmalar, artış ve azalış trendleri incelenmiş ve bu değişimlerin olası nedenleri tartışılmıştır. Ayrıca, söz konusu verilerin Türkiye ekonomisine katkıları, tarımsal hasıla içindeki payları, et ve süt üretimi açısından önemi ve gıda güvenliğine etkileri yorumlanmıştır.

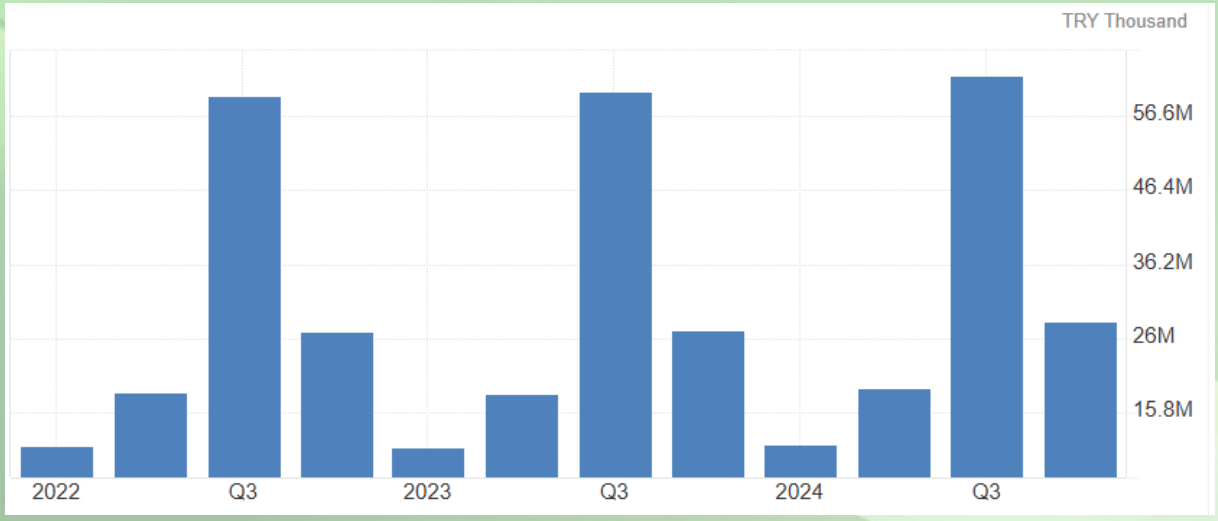
Bulgular ve Tartışma

Araştırma kapsamında incelenen TÜİK, Dünya Bankası ve FAO verilerinden hareketle, Türkiye'de tarımsal üretim ve özelde hayvansal üretimin ekonomik boyutu, yapısal özellikleri ve gelişim eğilimleri analiz edilmiştir. Elde edilen bulgular, Türkiye'nin 2023 yılında 1.118,25 milyar dolarlık GSYİH'si içerisinde tarım sektörünün %6'lık bir paya sahip olduğunu ve tarımsal üretimin içerisinde hayvansal üretimin %35 düzeyinde seyrettiğini göstermektedir. Büyükbaş hayvan varlığında 2018-2021 döneminde gözlenen artış trendinin ardından yaşanan düşüş ve 2024'teki kısmi toparlanma, küçükbaş hayvan sayılarında 2021'deki zirve noktasının ardından 2023'te yaşanan düşüş ve 2024'te gözlenen yeniden artış eğilimi, ve kümes hayvancılığında özellikle et tavuğu üretiminde 2024'te kaydedilen ciddi artış, hayvansal üretim sektörünün dinamik yapısını ortaya koymaktadır. Bu veriler ışığında, hayvansal üretimin ekonomik katkıları, gelişim potansiyeli ve karşılaştığı zorluklar aşağıda detaylı olarak sunulmaktadır.

Türkiye'nin hayvansal üretim sektörü, ulusal ekonomide kritik bir konuma sahiptir. Dünya Bankası verilerine göre, 2023 yılında Türkiye'nin 1.118,25 milyar dolarlık GSYİH'si (Şekil 1) içerisinde tarım sektörünün payı yaklaşık %6'dır ve bu tarımsal üretimin içerisinde hayvansal üretimin payı %35 civarındadır. Bu oran, Avrupa Birliği ülkelerindeki %45 düzeyinin altında kalarak, geliştirilebilecek önemli bir potansiyel olduğunu göstermektedir. 2024 yılının üçüncü çeyreğinde tarımsal GSYİH 62.039.644 bin TL ile rekor seviyeye ulaşmış, ancak dördüncü çeyrekte 28.375.071 bin TL'ye gerileyerek belirgin bir dalgalanma sergilemiştir. 1998-2024 döneminde tarımsal GSYİH ortalaması 22.774.874,69 bin TL olarak gerçekleşmiş, bu da tarım ve hayvancılık sektörünün ekonomideki istikrarlı ama dalgalı seyrinin bir göstergesidir (Şekil 2). Türkiye'de hayvansal üretim sektörünün GSYİH içindeki payının, Avrupa Birliği ülkeleri ortalamasının (%45) altında kalması, bu alanda hâlen değerlendirilmeyi bekleyen önemli bir büyüme potansiyeli olduğunu göstermektedir (European Commission, 2023). 2024 yılı üçüncü çeyreğinde tarımsal GSYİH'nin rekor seviyeye ulaşması, uygun üretim ve yatırım koşulları sağlandığında sektörün ekonomiye ciddi katkılar sunabileceğini ortaya koymaktadır. Ancak dördüncü çeyrekte yaşanan keskin düşüş, tarım ve hayvancılık sektörünün iklimsel, yapısal ve piyasa koşullarına oldukça duyarlı olduğunu göstermektedir. Literatürde de benzer şekilde, tarım sektörünün mevsimsellik ve iklim değişkenliği nedeniyle ekonomik performansında dalgalanmalar yaşadığı vurgulanmaktadır (OECD, 2021). Türkiye'de hayvansal üretimin sürdürülebilirliği, yatırım ortamının güçlendirilmesi, üreticilerin desteklenmesi ve altyapının dijitalleşmesiyle doğrudan ilişkilidir (FAO, 2022). Bu bağlamda, istikrarlı büyümenin sağlanabilmesi için yalnızca üretim hacmi değil, aynı zamanda üretim kalitesi, lojistik ve pazarlama altyapısının da güçlendirilmesi gerektiği söylenebilir.

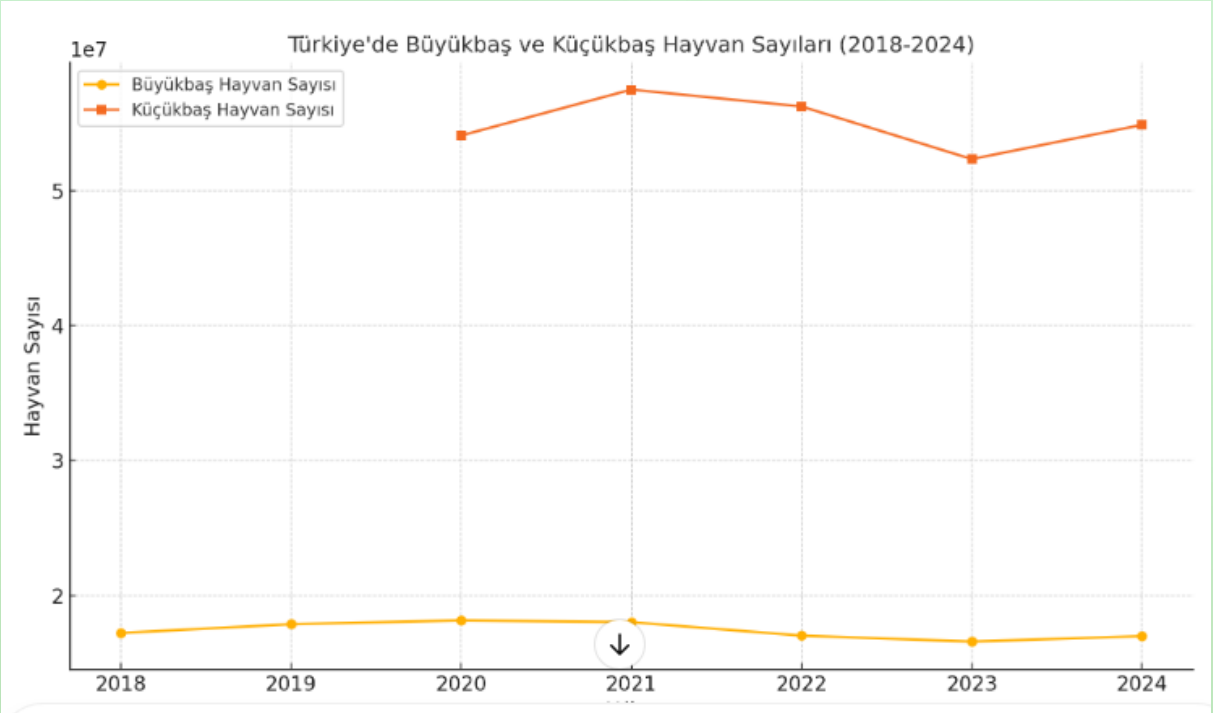


Şekil 1. 2013-2024 Türkiye GSYİH Rakamları (Dünya Bankası, 2025)



Şekil 2. Tarımın Türkiye GSYİH İçerisindeki Payı (TÜİK, 2025a)

Büyükbaş hayvan varlığında 2018-2021 arasında görülen artış trendi (17,2 milyondan 18,1 milyona) sonrasında yaşanan düşüş ve 2024'teki kısmi toparlanma (16.986.259 baş), sektördeki hassasiyeti ortaya koymaktadır. Benzer şekilde, küçükbaş hayvan sayısının 2020'de 54,1 milyondan 2021'de 57,5 milyona yükselmesi, ardından 2023'te 52,3 milyona gerilemesi ve 2024'te 54.902.668'e toparlanması, sektörün ekonomik koşullara ve politika değişimlerine ne denli duyarlı olduğunu göstermektedir (Şekil 3). Bu dalgalanmalar, yem maliyetleri, iklim koşulları, destekleme politikaları ve pazar dinamikleri gibi faktörlerden doğrudan etkilenmektedir.



Şekil 3. 2018-2024 Türkiye Büyükbaş ve Küçükbaş Hayvancılık rakamları (TÜİK, 2025b)

Türkiye'nin hayvansal üretim sektöründe dikkat edilmesi gereken en önemli husus, tarımsal üretim içerisindeki %35'lik payın AB standartlarına yaklaştırılması için stratejik politikaların geliştirilmesidir. Bu artış, katma değeri yüksek ürünlerle ekonomiye daha fazla katkı sağlayacaktır. Ayrıca, yem maliyetlerinin düşürülmesi için yerli yem hammaddesi üretiminin teşvik edilmesi, yem bitkileri ekiliş alanlarının genişletilmesi ve alternatif protein kaynaklarının araştırılması zorunlu hale gelmiştir. Yerli ırkların verimliliklerinin artırılması ve adaptasyon kabiliyetlerinin güçlendirilmesi için kapsamlı ıslah programları uygulanması da sektörün sürdürülebilirliği açısından kritik önem taşımaktadır.

İklim değişikliğinin hayvan varlığı üzerindeki etkilerini azaltmak için kuraklığa dayanıklı üretim sistemleri ve su kaynaklarının verimli kullanımı teşvik edilmelidir. Küçük ve orta ölçekli üreticilerin kooperatifler ve üretici birlikleri altında örgütlenmesinin desteklenmesi, pazarlama kanallarına erişimlerini kolaylaştıracak ve değer zincirindeki paylarını artıracaktır. Hayvancılık işletmelerinde dijital teknolojilerin ve akıllı çiftlik sistemlerinin yaygınlaştırılması ile verimlilik artışı sağlanması, hastalık yönetiminin geliştirilmesi ve üretim maliyetlerinin düşürülmesi mümkün olacaktır. İklim değişikliğinin hayvan varlığı üzerindeki olumsuz etkilerinin azaltılması için kuraklığa dayanıklı yem bitkilerinin ve üretim sistemlerinin teşviki, literatürde giderek daha fazla önerilen bir stratejidir. Özellikle su kaynaklarının daha verimli kullanılması, hem üretimin sürdürülebilirliğini artırmakta hem de çevresel baskıyı azaltmaktadır (Thornton vd., 2009). Küçük ve orta ölçekli üreticilerin kooperatifler ve üretici birlikleri çatısı altında örgütlenmeleri, değer zincirinde daha etkin bir rol oynamalarını sağlamakta ve pazarlama süreçlerinde rekabet güçlerini artırmaktadır (Birner & Resnick, 2010). Bu yapılanmalar sayesinde çiftçiler, hem girdi temininde hem de ürün pazarlamasında daha güçlü bir pozisyon elde etmektedir. Öte yandan, hayvancılık işletmelerinde dijital teknolojilerin ve akıllı çiftlik sistemlerinin entegrasyonu ile üretim süreci daha verimli, izlenebilir ve maliyet etkin hâle gelmektedir. Sensör teknolojileri, uzaktan sağlık takibi ve otomatik yemleme sistemleri gibi uygulamalar sayesinde hem hayvan refahı artmakta hem de üreticiye anlık veri ile karar alma kolaylığı sağlanmaktadır (Wolfert vd., 2017). Ayrıca, dijitalleşme sayesinde erken hastalık teşhisi ve etkin sürü yönetimi gibi kritik konularda da önemli gelişmeler yaşanmaktadır. Bu bulgular, iklim değişikliği ve piyasa dalgalanmaları gibi dışsal şoklara karşı hayvansal üretim sistemlerinin daha dirençli hâle getirilmesi gerektiğini ortaya koymaktadır.

Hayvansal üretimdeki dalgalanmaların önüne geçmek için uzun vadeli, öngörülebilir ve sonuç odaklı destekleme politikalarının uygulanması elzemdir. Hayvancılık sektörünün kırsal istihdamdaki kritik rolü gözetilerek, genç

çiftçilerin sektörde kalmasını sağlayacak teşvikler ve eğitim programları geliştirilmelidir. Hayvansal ürünlerde katma değerli üretimin teşvik edilmesi ihracat potansiyelini artıracak, özellikle coğrafi işaretli yerel ürünlerin desteklenmesi rekabet avantajı sağlayacaktır. Hayvan sağlığı ve refahı standartlarının yükseltilmesi, antimikrobiyal direncin azaltılması ve çevresel etkilerin minimize edilmesi için bütüncül yaklaşımların benimsenmesi de sektörün geleceği için hayati önem taşımaktadır.

Türkiye'nin hayvansal üretim sektöründeki dalgalanmaların azaltılması ve istikrarlı büyümenin sağlanması, gıda güvenliği, kırsal kalkınma ve ekonomik istikrar açısından stratejik öneme sahiptir. GSYİH içindeki payı ve kırsal ekonomideki rolü düşünüldüğünde, hayvansal üretimin sürdürülebilir kalkınma hedefleriyle uyumlu biçimde geliştirilmesi, ulusal ekonomiye önemli katkılar sağlayacak ve Türkiye'nin bu alandaki rekabet gücünü artıracaktır.

Türkiye'de hayvansal üretimin önemli bileşenlerinden biri olan kümes hayvancılığı, özellikle et ve yumurta üretimi açısından stratejik bir konuma sahiptir. TÜİK verilerine göre, 2018–2024 döneminde kümes hayvanı varlığında dikkate değer değişimler yaşanmıştır.

Türkiye 2018-2024 Kümes Hayvanları Üretim Rakamları (2018-2024)

Yıl	Et tavuğu (milyon)	Yumurta Tavuğu (milyon)	Hindi (Milyon)	Kaz (Milyon)	Ördek (milyon)
2018	223,2	124,0	3,5	1,2	0,6
2019	226,1	122,4	3,4	1,3	0,6
2020	239,4	121,3	3,2	1,4	0,5
2021	233,1	118,6	3,1	1,4	0,5
2022	228,7	122,8	2,8	1,5	0,5
2023	221,7	129,1	3,4	1,5	0,5
2024	270,5	109,1	2,8	1,4	0,4

Kaynak: TÜİK, 2025c

Türkiye'de kümes hayvancılığı son yedi yılda dalgalı bir seyir izlemiştir. Et tavuğu üretimi 2018-2020 arasında yükseliş göstermiş, ardından 2020-2023 döneminde düşüşe geçmiş, ancak 2024'te %22'lik etkileyici bir artışla 270,5 milyon adede ulaşmıştır. Bu durum, beyaz et tüketimindeki artışa ve sektördeki yatırımların olumlu sonuçlarına işaret etmektedir. Buna karşın, yumurta tavuğu sayısında 2023'ten 2024'e kadar ciddi bir düşüş yaşanmış, %15,5'lik azalmayla 129,1 milyondan 109,1 milyona gerilemiştir. Bu düşüş, yem maliyetlerindeki artış, hastalık salgınları veya pazar koşullarındaki değişimlerden kaynaklanabilir ve acil müdahale gerektirmektedir.

Hindi üretimi 2018'den 2022'ye kadar genel bir düşüş eğilimi göstermiş, 2023'te kısa süreli bir toparlanma yaşansa da 2024'te tekrar 2,8 milyon adede gerilemiştir. Hindi eti, sağlıklı beslenme arayışında olan tüketiciler için önemli bir alternatif olduğundan, bu düşüş trendi tersine çevrilmelidir. Kaz üretimi 2018-2022 arasında hafif bir artış göstermiş, ancak son iki yılda 1,5 milyondan 1,4 milyona gerilemiştir. Ördek üretimi ise yedi yıllık süreçte 0,6 milyondan 0,4 milyona düşmüştür. Bu alternatif kümes hayvanları, ülke genelinde yaygın olmamakla birlikte, belirli bölgelerde ekonomik potansiyele sahiptir ve çeşitlendirme stratejisi açısından desteklenmelidir.

Türkiye'nin kümes hayvancılığı sektöründe öncelikli olarak yumurta tavukçuluğuna özel önem verilmesi gerekmektedir. 2024'teki keskin düşüş, temel protein kaynağı olan yumurta üretimini olumsuz etkileyebilir ve fiyatları yükseltebilir. Yem girdilerinin maliyetini düşürmeye yönelik politikalar, hastalıklarla mücadele programları ve küçük-orta ölçekli üreticilere finansal destek sağlanması bu alanda öncelikli adımlar olmalıdır. Bununla birlikte, hindi yetiştiriciliğinin canlandırılması da sektörel çeşitlilik açısından kritiktir. Hindi eti, düşük yağ ve yüksek protein içeriğiyle sağlıklı beslenme trendlerine uygun bir üründür, dolayısıyla üretiminin teşvik edilmesi hem iç pazar hem de ihracat potansiyeli açısından faydalı olacaktır. Türkiye'nin kümes hayvancılığı sektörü, hayvansal üretim içinde önemli bir yer tutmakta olup özellikle yumurta tavukçuluğu, temel protein kaynağı sunması açısından stratejik öneme sahiptir. Ancak 2024 yılında yaşanan üretim düşüşü, bu kaynağın sürdürülebilirliğini tehdit etmektedir. FAO (2023) verilerine göre, yumurta üretimindeki azalma hem fiyat dalgalanmalarına neden olmakta hem de kırılgan hanehalklarını doğrudan etkilemektedir. Bu bağlamda yem maliyetlerinin düşürülmesi, biyogüvenlik önlemlerinin artırılması ve üreticilere finansal destek sağlanması kritik müdahale alanlarıdır (OECD, 2022b).Öte yandan, Türkiye'de üretim hacmi görece düşük olan hindi yetiştiriciliği de önemli bir potansiyel barındırmaktadır. Hindi eti, düşük yağ ve yüksek protein içeriğiyle sağlıklı beslenme eğilimleriyle örtüşmekte ve bu da hem iç pazar hem de ihracat açısından yeni fırsatlar yaratmaktadır (Sipahi ve Cevger, 2010). Literatürde de belirtildiği gibi, hayvansal üretimde tür çeşitliliğinin artırılması, gıda güvencesi ve sektörün esnekliği açısından stratejik bir öneme sahiptir (FAO, 2020). Dolayısıyla hindi yetiştiriciliğinin desteklenmesi, Türkiye'nin kümes hayvancılığı sektöründe yapısal bir dönüşüm yaratabilir.

Et tavuğu üretimindeki 2024 artışının sürdürülebilirliği sağlanmalı, ancak bu büyümenin kalite ve hayvan sağlığından ödün vermeden gerçekleşmesi gözetilmelidir. Organik ve serbest gezen tavuk yetiştiriciliğine yönelik teşvikler, katma değerli ürünlerle sektörün rekabet gücünü artırabilir. Kaz ve ördek yetiştiriciliği gibi niş alanlarda bölgesel kalkınma projeleri desteklenerek, bu türlerin yetiştiricilik gelenekleri olan yörelerde ekonomik canlanma

sağlanabilir. Sonuç olarak, Türkiye'nin kümes hayvancılığında dengeli ve çeşitlendirilmiş bir üretim yapısına kavuşması, hem gıda güvenliği hem de kırsal kalkınma açısından stratejik önem taşımaktadır.

Sonuç

Türkiye'de tarım sektörü içerisinde hayvansal üretimin ekonomik katkıları ve geleceğe yönelik perspektiflerini analiz eden bu çalışmada, önemli bulgulara ulaşılmıştır. Hayvansal üretimin tarımsal ekonomi içerisindeki %35'lik payı, AB ülkelerindeki %45 oranının altında kalması, sektörün geliştirilmesi gereken önemli bir potansiyele sahip olduğunu göstermektedir. 2018-2024 dönemi verileri incelendiğinde, hem büyükbaş ve küçükbaş hayvan varlığında hem de kümes hayvancılığında dalgalanmaların yaşandığı, bu dalgalanmaların yem maliyetleri, iklim koşulları, hastalıklar ve politika değişikliklerinden kaynaklandığı görülmektedir.

Büyükbaş hayvancılıkta 2018-2021 arası görülen artış eğiliminin ardından 2022-2023'te yaşanan düşüş ve 2024'teki kısmi toparlanma, sektörün hassasiyetini ortaya koymaktadır. Benzer şekilde, küçükbaş hayvan varlığı 2021'de zirve yapmasına rağmen, sonraki yıllarda düşüş yaşamış ve 2024'te yeniden artış eğilimine girmiştir. Kümes hayvancılığında ise özellikle 2024 yılında et tavuğu üretiminde %22 artış kaydedilirken, yumurta tavuğu sayısında %15,5'lik ciddi bir düşüş yaşanmıştır. Bu durum, kümes hayvancılığı alt sektörlerinde dengesiz bir gelişim olduğunu göstermektedir.

Çalışma sonucunda, Türkiye'nin hayvansal üretim sektöründe sürdürülebilir kalkınma için bazı stratejik adımlar atılması gerektiği sonucuna varılmıştır. Öncelikle yem maliyetlerinin düşürülmesi için yerli hammadde üretiminin artırılması ve alternatif protein kaynaklarının araştırılması gerekmektedir. Yerli hayvan ırklarının verimliliklerinin artırılması ve adaptasyon kabiliyetlerinin güçlendirilmesi için ıslah programlarının yaygınlaştırılması önem arz etmektedir. İklim değişikliğinin etkilerine uyum sağlamak için kuraklığa dayanıklı üretim sistemleri ve verimli su kullanım yöntemleri geliştirilmelidir.

Ayrıca, küçük ve orta ölçekli üreticilerin kooperatifler ve üretici birlikleri altında örgütlenmesinin desteklenmesi, pazara erişimlerini kolaylaştıracak ve değer zincirindeki paylarını artıracaktır. Hayvancılık işletmelerinde dijital teknolojilerin ve akıllı çiftlik sistemlerinin yaygınlaştırılması, verimlilik artışı ve maliyet düşüşü sağlayacaktır.

Sektörde istikrarlı büyümenin sağlanması için uzun vadeli, öngörülebilir ve sonuç odaklı destekleme politikalarının uygulanması elzemdir. Genç çiftçilerin sektörde kalmasını teşvik edecek programlar geliştirilmeli, hayvansal ürünlerde katma değerli üretim desteklenmelidir. Özellikle coğrafi işaretli yerel ürünlerin teşvik edilmesi, rekabet avantajı sağlayacaktır.

Sonuç olarak, Türkiye'nin hayvansal üretim sektöründe dengeli, sürdürülebilir ve katma değerli üretime odaklanan bir gelişim stratejisi, hem gıda güvenliği hem de kırsal kalkınma hedeflerine katkı sağlayacaktır. Hayvansal üretimin GSYİH'deki payının artırılması ve AB standartlarına yaklaştırılması için bütüncül politikalar geliştirilmesi, Türkiye'nin bu alandaki rekabet gücünü artıracak ve sürdürülebilir bir hayvancılık sektörü için sağlam temelleri oluşturacaktır.

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Maize Productivity Transitions among Farmers in Nigeria

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Abstract

The study analyzes maize farming productivity state transitions in Nigeria using data from the 2015 and 2018 General Household Survey-Panel to identify the socioeconomic and institutional factors influencing productivity development over time. Nigeria's national food security and rural livelihoods depend on maize, an essential staple crop. Maize farmers lag behind local competitors because their production system operations are insufficient. The study used Markov Chain analysis and multinomial logistic regression to analyze productivity category movement patterns and their corresponding determinants. Among the farmers from 2015, only 71.4 percent maintained productive status in 2018, while 28.6 percent left the category. A total of 79.2% of non-productive farmers transformed into productive groups between 2015 and 2018 based on Markov Chain analysis. In the long run, it is predicted that the majority of the farmers, 65%, will remain productive. The regression analysis confirmed that age, together with household size and sex, demonstrated statistical importance in the determination of productivity transitions. Older farmers and large households experienced increased chances of productive continuation and initiation, but men showed a reduced likelihood of exiting productivity. Despite many farmers transitioning into productive zones, limitations exist because of restricted credit access, minimal contact with extension services, and small production areas. Productivity, sustainability, and maize farmer resilience require specific interventions, including better extension programs, affordable credit, and cooperative membership enhancement. The research outcome makes valuable contributions to governmental authorities who aim to improve agricultural program results while promoting sustainable maize development in Nigeria.

Key Words: *Productivity Transition, Maize, Nigeria, General Household Survey, Markov Chain*

Introduction

Maize is the most significant cereal crop in sub-Saharan Africa, which is farmed by over 50% of the continent's population (FAO, 2006). It is the principal cereal crop in Nigeria and the principal cereal crop in West Africa (Ayedun, 2018). Maize (Zea mays), a staple crop, holds a significant position in Nigeria's agricultural economy, contributing to food security and livelihood for millions (Wossen *et al., 2023)*. As Africa's second-largest maize producer, Nigeria recorded an estimated 11 million metric tons of production in 2019, harvested from over 6.8 million hectares (Wossen *et al*., 2023). Despite its expansive cultivation, productivity levels have remained stagnant at approximately 1.7 tons per hectare, markedly lower than those of other leading African producers such as South Africa and Ethiopia, with 4.9 and 4.2 tons per hectare yields, respectively (PwC, 2021).

The productivity transition among Nigerian maize farmers is shaped by a complex interplay of factors, including technology adoption, resource allocation, and socioeconomic dynamics (Ibitola *et al.,* 2019). Recent studies highlight the critical role of improved maize varieties in bridging the productivity gap. For instance, adopting these varieties has been shown to enhance yields by up to 38.7%, driven primarily by technological advancements rather than improvements in managerial efficiency (Olasehinde *et al*., 2023). However, the persistent underutilization of efficient farming practices underscores the need for targeted interventions.

According to Mekonnen (2021), there has been extensive nationwide promotion toward advancing, propagating, and accepting enhanced crop varieties and fertilizer technology; still, the nation's agriculture industry is characterized by low productivity. Interventions seem important in raising the output level in a particular setting, but these increases are prone to inefficiency, particularly when the available technology is not used effectively. These issues are further compounded by climate variability and declining soil fertility, which disproportionately affect smallholder farmers who constitute the majority of maize producers in Nigeria (Ogbodo *et al.,* 2018). Addressing these challenges requires a multifaceted approach that includes improving access to agricultural inputs, promoting sustainable farming practices, and enhancing market linkages.

This study explores the dynamics of productivity transitions among maize farmers in Nigeria, examining the influence of socio-economic factors. Understanding these transitions is critical for formulating policies that improve maize yields, enhance the livelihoods of smallholder farmers, and contribute to national food security.

Materials and Methods

Study Area

The study was conducted in Nigeria, West Africa, at Latitude 9° 04' 39.90" N and Longitude 8° 40'. As of April 2025, the population of Nigeria is approximately 237 million 2025. 38.84" E, Africa's most populous nation and the sixth most populous country globally (Worldometer, 2025). The Federal Capital Territory, Abuja, and 36 states comprise the federal constitutional republic, the Federal Republic of Nigeria. The West African nation of Nigeria is bordered on land by the Republic of Benin to the west, by Chad and Cameron to the east, by Niger to the north, and by the Atlantic Ocean to the south. Nigeria is a 923,768 km³ nation in Africa. Nigeria has just two seasons, just like the rest of West Africa and other tropical regions. There are two of these: the rainy and the dry seasons. While the rainy season is greatly impacted by an air mass originating from the South Atlantic Ocean, popularly known as the South Western wind, the dry season is accompanied by an air mass packed with dust from the Sahara Desert, commonly known as Harmattan (Jeník & Hall, 1966). A brief and longer dry season comes between and after each peak in the two-fold rainfall maximum that the southern part of Nigeria experiences.

Data Source

The data for this study were obtained from the 2015 and 2018 Nigerian General Household Surveys (GHS). The GHS-Panel component in Nigeria is part of a regional initiative to improve agricultural statistics in Sub-Saharan Africa. The data was collected by the National Bureau of Statistics (NBS) in collaboration with the Federal Ministry of Agriculture and Rural Development (FMA&RD), National Food Reserve Agency (NFRA), World Bank (WB), and Bill and Melinda Gates Foundation (BMGF). The GHS-Panel aims to develop a leading paradigm for agricultural data collection, foster inter-institutional collaboration, and analyse welfare indicators and socioeconomic features. The 5,000-household GHS-Panel poll represents all households and geopolitical zones (urban and rural). A subset of the GHS sample homes is the GHS panel. The General Household Survey used a multi-stage stratified sample design. Nigeria's GHS sample includes 60 Enumeration Areas (EAs) or Primary Sampling Units (PSUs) from its 37 states, totalling 2220 EAs nationally. A survey of 456 respondents was used across all states and regions. Data on yield and household socioeconomic factors, including size, age, gender, marital status, education level, farm size, access to credit, and extension services, were gathered.

Analytical Technique

Markov Chain

The Markov chain model was used to determine the level of productivity transition among the maize farmers. The Markov model is converted into probability values of entering and exiting productivity by dividing each item by the corresponding row total to give the transition probability below.

X_{11} X_{21} (X_{12} X_{22})

Also, the vector of initial probability P (o) was obtained by dividing each column total by the total. Thereafter, we tried to see the proportion of households that will be in each category in the subsequent periods by using

$P(k) = P(o)\,Pk$

Where k is the period in seasons.

Long-term equilibrium (when the proportion of households entering productivity equals the proportion exiting it) was obtained by using

$eP = e$

$(e_1, e_2)\,(X_{11}\ X_{12}, X_{21}\ X_{22}) = (e_1, e_2)$

The solution to the above equation produced e_1 and e_2, the proportion of households that will be productive and at equilibrium in the long run.

Where e_1 = probability of households that will be productive at equilibrium

e_2 = probability of households that will be non-productive at equilibrium

Multinomial Logistics Regression

The multinomial logistics regression model was used to estimate the determinant of productivity transition among the maize farmers. Multinomial logistic regression was used to model nominal outcome variables, in which the log odds of the outcomes are modeled as a linear combination of the predictor variables. A multinomial logistic regression was performed to create a model of the relationship between the predictor variables and membership in the other groups. Multinomial logistic regression is the extension for the (binary) logistic regression when the categorical dependent outcome has more than two levels (Anderson & Rutkowski, 2008).

Following Adepoju (2012) and Ayantoye (2011), the multinomial logit regression model can be expressed explicitly as

$Y_0 = \alpha_0 + \beta_{10}X_1 + \beta_{20}X_2 + \ldots\ldots\ldots\ldots + \beta_{n0}X_n + \varepsilon_{i0}$ .....(1)

$Y_1 = \alpha_1 + \beta_{11}X_1 + \beta_{21}X_2 + \ldots\ldots\ldots\ldots + \beta_{n1}X_n + \varepsilon_{i0}$ .....(2)

$Y_2 = \alpha_2 + \beta_{12}X_1 + \beta_{22}X_2 + \ldots\ldots\ldots\ldots + \beta_{n}2_{Xn} + \varepsilon_{i0}$ .....(3)

$Y_3 = \alpha_3 + \beta_{13}X_1 + \beta_{23}X_2 + \ldots\ldots\ldots\ldots + \beta_{n}3_{Xn} + \varepsilon_{i0}$ .....(4)

Y_0 = those who entered productivity (which is the reference case)

Y_1 = those who are consistently productive

Y_2 = those who exited productivity

Y_3 = those who are always non-productive
$X_1 \ldots X_n$ represent the vector of the explanatory variables
$\beta_1 \ldots \beta_n$ represent the parameter coefficients.
ε_i = represents the independently distributed error terms
$\alpha_0 - \alpha_3$ = shows the intercept or constant terms.

Results and Discussion

This section discusses the socio-economic characteristics of the maize farmers. These include Sex, Age, Marital status, Education level, Household size, Credit access, Membership in cooperatives, etc. As shown in Table 1, 79.6% of the respondents were male, and 20.4% were female. The majority, approximately 64%, had only primary education. In comparison, about 76% of the respondents were married. In comparison, the majority of about 98% have no access to extension contact, while the majority of about 90% among the respondents have no access to credit. In contrast, the mean age of the respondents was 53 years, the average farm size cultivated for maize was 1.17 hectares, and the average household size was nine persons.

Table 1: Demographic characteristics of the respondents in the study area

Demographic variables	Frequency	Percentage	Mean
Sex			
Male	363	79.61	
Female	93	20.39	
Level of Education			
No education	29	6.36	
Primary	293	64.25	
Secondary	116	25.44	
Tertiary	18	3.95	
Marital status			
Unmarried	109	23.90	
Married	347	76.10	
Access to extension service			
Yes	11	2.41	
No	445	97.59	
Access to credit			
Yes	44	9.65	
No	412	90.35	
Age			53 years
<21	5	1.10	
21-30	13	2.85	
31-40	71	15.57	
41-50	111	24.34	
51-60	117	25.66	
>60	139	30.48	
Farm size			1.17 hectares
1	267	58.55	
1-5	178	39.04	
>5	11	2.41	
Household size			9 persons
<6	102	22.37	
6-10	236	51.75	
>10	118	25.88	
Total	456	100.00	

Level of Productivity Transition among Maize Farmers

Table 2 shows the results of the transition matrix and their probabilities. The results are in line with the work of Baulch and McCulloch (2002). The results revealed that 71.4% of farmers who were productive in 2015 remained productive in 2018, while 28.6% of those who were productive in 2015 transitioned to non-productive in 2018. Also, 79.2% of non-productive people in 2015 transitioned to being productive in 2018, while 20.8% in 2015 remained non-productive in 2018.

Furthermore, the result showed that in the short run, the probability that a farmer will be productive is 77.1%, while the probability that a farmer will be non-productive is 22.8%.

In Equilibrium, i.e, the long run, the probability that a maize farmer will be productive in the long run is 65.0%, while the probability that the maize farmer will be non-productive in the long run is 35.0%. This shows that most maize farmers will be productive in the long run.

Table 2: Level of Productivity Transition among Maize Farmers

2015	2018		Total
	Productive	Non-Productive	
Productive	85 (71.4)	34(28.6)	119 (26.1)
Non-Productive	267 (79.2)	70 (20.8)	337 (73.9)
Total	352 (77.1)	104 (22.8)	456 (100)

Productivity Transitions Across Demographic Characteristics of the Maize Farmer

The section discusses productivity transitions among maize farmers based on demographic characteristics such as sex, age, education, marital status, and farm size. Key findings from Table 3 show that 81% of consistently productive farmers are male; 56% of those who exited productivity are female; 85% of new productive farmers are male; 73% of non-productive farmers are male. The majority of all the groups (always productive, exited, entered, non-productive) have primary education, ranging from 62% to 79%. 42% of consistently productive farmers are aged 51-60; 47% of those who exited productivity are aged 51-60 or above 60. In terms of marital status, 78% of consistently productive farmers are married; 56% of those who exited productivity are unmarried; 81% of new productive farmers are married; 69% of non-productive farmers are married Likewise, all groups have less than 1 hectare of land, ranging from 54% to 79%. Most farmers in all groups have 6-10 household members access. 97% of always productive and exited farmers lack access to extension agents, while 99% of those who entered productivity farmers lack access; 96% of non-productive farmers lack access. The majority of the farmers do not have access to credit, and this becomes evident in the groups as 95% of always productive farmers lack access; 82% of exited farmers lack access; and 90% of both new productive and non-productive farmers lack access.

Determinants of Productivity Transition among Maize Farmers

The multinomial logistics regression model was used to estimate the determinant of productivity transition among the maize farmers. As shown in the result, the P level of 0.00 ($P<0.005$) indicates that there is goodness of fit in the model. A unit increase in age will lead to a 0.1189 increase in being always productive compared to those entering productivity. It is significant at 10%. This indicates that an increase in age will contribute to an increase in 2015 and 2018 relative to entering productivity. A unit increase in household size will lead to a 0.0594 increase in being always productive compared to those entering productivity. It is significant at 5%. This means that an increase in household size will contribute to an increase in being productive in the years 2015 and 2018 relative to entering productivity. Tura *et al. (2010) agree* that household size significantly influences continued productivity among maize farmers. A unit increase in age will lead to a 0.3047 increase in exiting productivity compared to those entering productivity. It is significant at 10%. This indicates that an increase in age will contribute to increased existing productivity from 2015 to 2018 relative to entering productivity. A unit increase in household size will lead to a 0.0808 increase in exiting productivity compared to those entering productivity. It is significant at 5%. This means that an increase in household size will contribute to an increase in exiting productivity from 2015 to 2018 relative to entering productivity. Idris *et al.* (2015) *indicate that household size is a factor affecting the efficiency and productivity of maize farmers*. Being a male farmer will lead to a 2.2269 decrease in exiting productivity compared to being a female farmer relative to those entering productivity. It is significant at 1%. This means that being a male farmer will decrease exiting productivity compared to being a female farmer from 2015 to 2018 relative to entering productivity.

Being a male farmer will lead to a 0.7137 decrease in non-productivity compared to being a female farmer relative to those entering productivity. This is significant at 5%. This means that being a male farmer will decrease non-productivity compared to being a female farmer in 2015 and 2018 relative to entering productivity.

Table 3: Distribution of Productivity Transitions across Socioeconomic characteristics

Variables	Always Productive Freq (%)	Exit Productivity Freq (%)	Entered Productivity Freq (%)	Always Non-Productive Freq (%)	Total Freq (%)
Sex					
Male	69 (81.2)	15 (44.1)	228 (85.4)	51 (72.9)	363 (79.61)
Female	16 (18.8)	19 (55.9)	39 (14.7)	19 (27.1)	93 (20.4)
Educational level					
No formal	10 (11.8)	0 (0)	18 (6.7)	1 (1.4)	29 (6.36)
Primary	53 (62.3)	27 (79.4)	161 (60.3)	52 (74.3)	293 (64.2)
Secondary	22 (25.9)	7 (20.6)	73 (27.3)	14 (20.0)	116 (25.4)
Tertiary	0 (0)	0 (0)	15 (5.6)	3 (4.3)	18 (3.9)
Age					
<21	0(0)	0 (0)	5(1.9)	0(0)	5(1.1)
21-30	3(3.5)	0(0)	8(3.0)	2(2.9)	13(2.8)
31-40	14(16.5)	2(5.9)	48(18.0)	7(10.0)	71(15.6)
41-50	15(17.7)	0(0)	76(28.5)	20(28.6)	111(24.3)
51-60	36(42.3)	16(47.1)	59(22.1)	6(8.6)	117(25.7)
>60	17(20.0)	16(47.1)	71(26.6)	35(50.0)	139(30.5)
Marital status					
Unmarried	18(21.2)	19(55.9)	50(18.7)	22(31.4)	109(23.9)
Married	67(78.8)	15(44.1)	217(81.3)	48(68.6)	347(76.1)
Farm size					
<1	50(58.8)	27(79.4)	145(54.3)	45(64.3)	267(58.5)
1-5	34(40.0)	5(14.7)	117(43.8)	22(31.4)	178(39.0)
>5	1(1.2)	2(5.9)	5(1.9)	3(4.3)	11(2.4)
Household size					
<6	12(14.1)	9(26.5)	58(21.7)	23(32.9)	102(22.4)
6-10	49(57.6)	20(58.8)	137(51.3)	30(42.9)	236(51.7)
>10	24(28.2)	5(14.7)	72(27)	17(24.3)	118(25.9)
Extension contact					
Yes	3(3.5)	1(2.9)	4(1.5)	3(4.3)	11(2.4)
No	82(96.5)	33(97.1)	263(98.5)	67(95.7)	445(97.6)
Access to credit					
Yes	4(4.7)	6(17.6)	27(10.1)	7(10.0)	44(9.6)
No	81(95.3)	28(82.3)	240(89.9)	63(90.0)	412(90.4)
Total	**85 (100)**	**34 (100)**	**267 (100)**	**70 (100)**	**456 (100)**

Table 4: Determinants of Productivity Transition among Maize Farmers

Productivity Transition	Always Productive		Exited Productivity		Always Non-Productive	
	Coefficient (Standard Error)	P>z	Coefficient (Standard Error)	P>z	Coefficient (Standard Error)	P>z
Age	0.12(0.069)***	0.083	0.305(0.158)***	0.054	-0.035 (0.058)	0.541
Household Size	0.059 (0.028)***	0.035	0.081 (0.035)**	0.022	0.001 (0.033)	0.964
Farm size	-0.124 (0.110)	0.262	0.110 (0.173)	0.526	0.098 (0.102)	0.336
Sex (Male)	-0.515(0.362)	0.155	-2.227 (0.476)*	0.000	-0.714 (0.359)	0.047
Cooperative (Yes)	-0.002 (0.647)	0.997	0.874 (0.659)	0.185	0.324 (0.572)	0.571
Credit (Yes)	-0.824 (0.559)	0.140	0.633 (0.557)	0.256	-0.017 (0.4664)	0.971
Log Likelihood = 468.52835 Number of obs. = 456 LR chi^2 (21) = 73.23 Prob > chi^2 = 0.0000 Pseudo R^2 = 0.0725						

*, **, *** signifies 1%, 5%, 10%, respectively.

Conclusion

This study examined the productivity transitions among maize farmers in Nigeria, focusing on factors influencing their movement between productivity categories over time. The findings revealed that while a significant proportion of farmers (71.4%) remained consistently productive, 28.6% transitioned out of productivity due to limited access to credit, small farm sizes, and lack of support from extension services. Additionally, farmers who entered productivity between 2015 and 2018 showcased the positive impact of socioeconomic variables, including household size and education levels. However, the persistence of non-productivity among a minority of farmers highlights structural and operational challenges within the maize farming sector.

Recommendations

Based on the findings, policymakers should strengthen rural financial institutions to provide affordable credit facilities tailored to smallholder farmers. This intervention would mitigate financial constraints and enable farmers to invest in productivity-enhancing inputs and technologies. Expanding the network of extension agents is critical to disseminating knowledge about improved farming practices and technologies. This includes training programs that emphasize sustainable farming and resource management strategies. The study also recommended encouraging the formation of cooperatives, which can facilitate resource pooling, reduce operational costs, and enhance access to markets and financial resources. Such collaborative frameworks have been proven to improve productivity among smallholder farmers. The government and private sector must also invest in rural infrastructure, including roads and storage facilities, to reduce post-harvest losses and improve market access. By implementing these recommendations, productivity transitions among maize farmers in Nigeria can be significantly improved, fostering a more resilient and sustainable agricultural sector.

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ID: 650

Bioecological and Faunistic Investigation of Insect Taxa in Patato Agricultural Areas and Surroundings of Derinkuyu District

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Abstract

Insects (Arthropoda: Insecta) are among the most important organisms of our planet in terms of biodiversity, ecological balance and economic effects. Our country has a rich insect fauna thanks to its location between the Asian and European continents, different climatic conditions and diverse vegetation. However, studies on insect diversity in Turkey are limited to certain regions, and there is a lack of taxonomic information on the insect fauna structure of arid and semiarid ecosystems and agricultural areas, especially in Central Anatolia. This research was conducted in the areas where potato farming is carried out and their surroundings in Derinkuyu district of Nevşehir province, which is located in the Central Anatolia Region and has great importance in terms of the regional economy, and aims to determine insect species diversity and ecological roles. Field studies were carried out between March and November 2022-2023. In the study, ecological and faunistic characteristics of Arthropoda: Insecta taxa were examined and the effects of environmental factors (temperature, humidity, precipitation) on insect populations were evaluated.

Keywords: *Insecta, Ecology, Biodiversity, Fauna, Derinkuyu, Potato plant*

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Evaluation of Cytotoxic Effect of Selenium Nanoparticles (An-SeNP) Obtained by Green Synthesis Method with *Inula viscosa* L. Extract on Hep-G2 Liver Cancer Cells

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Abstract

According to the World Health Organization (WHO) data, cancer is one of the most common causes of death worldwide today. In this study, the cytotoxic effects of selenium nanoparticles (An-SeNP) obtained by green synthesis method on human liver cancer cell line (Hep-G2) were investigated. *Inula viscosa* L. (Andız grass) extract was used during the synthesis process and two different synthesis methods were applied. In both methods, 10 mM SeO_2 solution and andız extract were mixed at a ratio of 4:1 and kept in a magnetic heater at 65°C for 12 hours. In the first method, a red color change was observed in the mixture, 10 mL of the obtained An-SeNPs were used directly, and the remaining part was centrifuged to separate the nanoparticles. Centrifuged and uncentrifuged samples were used in cell cultures within 2 days. In the second method, the color in the mixture turned orange, then it was kept in the oven for 12 hours and stored in the dark at room temperature for 30 days. The An-SeNPs obtained in this method were used for cell studies without centrifugation. Synthesized nanoparticles were characterized by UV-vis spectrophotometer, Zeta potential and Scanning Electron Microscope (SEM). In order to evaluate cytotoxic effects, An-SeNPs at different concentrations were incubated with Hep-G2 cells for 24 hours and cell viability was determined by MTT test. It was determined that An-SeNPs showed significant cytotoxic effects on Hep-G2 cells in all three applications

Key words: *Green synthesis, selenium nanoparticles, Inula viscosa, Hep-G2, cytotoxicity, MTT*

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Body Thermoregulatory Adaptations And Reproductive Potentials Of Yankassa Rams Fed Diets Containing Urea-Molasses Treated Cassava Peel Ensiled With Caged-Layer Droppings

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Abstract

This study was conducted to evaluate the physiological responses and reproductive performance of sheep fed diets containing urea-molasses treated cassava peels ensiled with caged layer droppings. The experiment took place at the Federal University of Agriculture Teaching and Research Farm, Adamawa. Twenty-one clinically healthy Yankassa breed of sheep, aged approximately 6 to 7 months, were used for the trial, which lasted for 63 days. Feed offered was measured daily. Statistical differences between mean values of the studied parameters were assessed using one-way repeated measures ANOVA. Thermoregulatory parameters—including heart rate, respiratory rate, earlobe temperature, and rectal temperature—showed no significant differences between treatment groups and the control group throughout the experimental period. Semen pH and abnormalities in sheep fed a diet with 25% replacement of urea-molasses treated cassava peels ensiled with caged layer droppings were not significantly different from the control group but were significantly better than those in the 50% replacement group. Conversely, reproductive parameters such as semen motility, live sperm percentage, semen concentration and volume, scrotal length, scrotal circumference, and libido were significantly improved in sheep fed the 50% replacement diet compared to the 25% replacement group, with no significant difference from the control. It can be concluded that the inclusion of urea-molasses treated cassava peels ensiled with caged layer droppings had no adverse effects on the thermoregulatory parameters of the sheep. Furthermore, the 50% replacement diet appears to be the most beneficial in terms of reproductive performance, falling within recommended nutritional standards for small ruminants.

Keywords; *Sheep nutrition, urea-molasses treated cassava peels, caged layer droppings, physiological responses, reproductive morphometrics,*

Introduction

The amount of animal protein consumed (4.5g/person/day) in the majority of emerging third-world nations, including Nigeria, is significantly less than the 35g daily recommended amount (FAO, 2001; Anaso et al. 2024c). Finding a new alternative method to stay competitive in the industry, improve performance while lowering production costs as much as possible, and provide consumers with high-quality protein is crucial to meeting the growing global demand for animal protein and preserving profitability (Anaso et al. 2021b; Anaso et al. 2024b; Anaso et al. 2025).

Anaso et al. (2023) assert that better nutrition can enhance livestock's reproductive and productive performance. Studies have been done to examine the effects of various feedstuffs on the reproductive performance and physiological response of cattle, with a small number focusing on goats and sheep. However, the exact mechanism by which feed affects ruminant reproductive performance and physiological response is still not fully scientifically proven (Anaso et al. 2024a; Anaso and Olafadehan 2025).

According to a study by Mohamed (2018), feeding Egyptian Barki ewes halophytic fodder shrubs (Atriplex, Acacia, and Cassava) did not pose any significant physiological risks or affect their ability to reproduce.

Despite having a low crude protein content and containing cyanogenic glycosides that are poisonous to livestock, cassava peels and other agroindustrial byproducts have been used to feed ruminant animals (Anaso et al., 2021a; Anaso et al., 2021b). However, they have undergone processing to maintain their nutritional value and lower the amount of cyanogenic glycosides and phytate (Oboh, 2006). To detoxify the cyanide concentration, a variety of processing techniques have been employed, including sun drying, ensiling, soaking, sun drying, and retting (Olafadehan, 2011). Molasses and poultry droppings have been utilized to increase the nutritional content of fibrous meals. Thus, ensiling the final product and treating it with caged-layer droppings and molasses can increase the nutritional content of cassava peels. This research focused on the thermoregulatory adaptations and reproductive potentials of Yankassa Rams fed complete diets containing caged layer droppings-molasses ensiled cassava peel as a substitute for corn bran.

Materials and Method

Study area

The research was conducted in Mubi town, the Northern Senatorial District of Adamawa State, Nigeria, at the Federal University of Agriculture Mubi Teaching and Research Farm's Monogastric Unit, the Morugo Agricultural/Research site was the study's location. Situated at the base of the Mandara Mountains, which divide

Nigeria from the Republic of Cameroun, Mubi is 1906 feet above sea level and falls between latitude 10.27 and longitude 13.28 (10.2801° N, 13.2774° E).

Source of feed ingredients and experimental animals

The cassava peels which were used for the experimental diet were obtained from selected farms during peeling of cassava in the post harvesting operation. Caged layer droppings were gotten from poultry farms within the university environment, while molasses and urea were gotten from Mubi Central market. The experimental rams were purchased from a nearby reputable animal farm Adamawa Nigeria.

Experimental animals, management and diets

Twenty one clinically healthy rams of Yankassa breed about 6 to 7 months with average initial body weight (BW) of 18.30 ± 0.46 kg were used for the experiment. The animals were ascertained to be healthy by a veterinary consultant, having vital parameters within normal ranges and showing no sign of disease. One week prior to the arrival of the animals, the surroundings and pens were thoroughly cleaned and disinfected with a strong antiseptic (morigad). On arrival, the rams were administered prophylactic treatment which included the intramuscular administration of oxytetracycline L.A. (Long acting) an antibiotic (1ml/10kg BW) against bacterial diseases. Ivomectin (0.5ml/25BW) was subcutaneously administered to the animals to protect them against endo-parasites inside the body cavity and ecto-parasites on the skin. Vitalyte was orally administered as anti-stress for a week in drinking water, before the animals were individually penned. Prior to isolation in their pen, they were allowed to adapt to their environment and the experimental diet for the period of one week before the commencement of experiment. The cages were cleaned thoroughly once a week.

Rams were weighed for their initial weight before starting feeding trials and they were randomized into three groups of similar body weight in completely randomized design (CRD). Experimental diets were fed to the animals and water given *ad libitum* through experimental period of 63 days.

100kg of dried cassava peel was collected, washed and allowed to wilt for 2 hours and mixed with 20kg of cage layers droppings and 10kg of molasses. It was allowed to for 30 days, then sundried for 3 days and grinded before taking to the laboratory for other analysis. The total amount of feeds offered daily and representative samples were on weekly basis and pooled together after the experiment. The quantity of feed provided and residue of each day was weighed to determine the feed intake of individual animal. The initial body weights of the goats were taken at commencement of the experiment and subsequently at 7 days interval in the morning before feeding.

Experimental diet

Three experimental diets were formulated with the inclusion of the three different types of supplement on cassava peel which include the cassava peel + molasses + cage layer droppings. T1 indicates 0% treated cassava peel replacement, T2 indicates 25% replacement of maize with treated cassava peel, and, T3 indicates the replacement of maize with 50% of treated cassava peel.

Table 1: Experimental diet with different inclusion level of treated cassava peel with urea-molasses ensiled with cage layer droppings on West Africa dwarf goat.

Ingredients (kg)	Treatment 1 0%replacmet of cassava peel	Treatment 2 25% replacement of cassava peel	Treatment 3 50% replacement of cassava peel
Maize	28	21	14
Treated cassava peel	0	7	14
GNC	18	18	18
Corn bran	21	21	21
TSH	28	28	28
Limestone	2	2	2
Salt	1	1	1
Urea	1	1	1
Vitamin premix	1	1	1
Cp	15.90	15.95	15.99
Total	100	100	100

Collection of thermoregulatory parameters

Every goat's heart rate, respiration rate, and rectal temperature were recorded twice a week at 10:00 a.m. A digital thermometer was used to measure the rectal temperature. According to Anaso et al. (2024b) and Anaso and Alagbe (2025), the sensory tip was cleaned with an antiseptic, lubricated with petroleum jelly Vaseline, and then placed into the rectum of a single animal at the temperature display of constant "C L0" on the thermometer's mini digital screen. Following the digital thermometer's beeping alarm signal, the device was taken out of the rectum, and the recorded body temperature was noted. After the alert signal beeped and the temperature was recorded, the digital thermometer was taken out of the earlobe. Using the seconds hand on an analog wristwatch, the number of abdominal movements per minute was counted for one minute, and the counts were recorded in order to determine the respiratory rate. A stethoscope positioned at the left side of the ribs was used to measure the heart rate.

According to Olafadehan et al. (2023, Anaso et al., 2024b; Anaso and Alagbe, 2025), the loop dope sound was the typical heart sound because it signified a full heart beat for one minute using the seconds hand on an analog wristwatch.

Testicular and semen parameters

According to Bratte et al. (1999), Akpa et al. (2012), and Anaso et al. (2024b), scrotal length (SL) was measured in centimeters using a flexible measuring tape as the distance along the scrotum's caudal surface, from its site of attachment to the tip of the scrotum. After the testes are pushed firmly into the scrotum, the greatest diameter surrounding the pendulous scrotum is known as the scrotal circumference (SC) (Akpa et al., 2006). A measuring tape was used to convert it to centimeters (cm).

As described by Zemjanis (1970), an automatic electro ejaculator (Autojact, Neovet) with 12 V and 5 A was used to electroejaculate all of the bucks from each session. A series of 1-35 stimuli lasting between 30 and 5 minutes is then shown.

By directly measuring the millimeter graduation of the collection vial, the volume of the semen samples was assessed right away, and the result was expressed in milliliters (mL). By visualizing the consistency of the ejaculates, the semen's appearance was assessed and categorized as watery, thick, milky, creamy marble, and creamy. Every semen sample was smeared, allowed to air dry, labeled, and stored for additional analysis.

10 µL of semen was mixed with 1 mL of Tris dilution buffer (Hydroxymethylaminomethane) (3.0 g), sodium citrate (2.0 g), and fructose (1.0 g) to measure the progressive motility. After that, an optical microscope (100x magnification) was used to examine a 10 µL aliquot of the diluted semen sample that had been placed between a heated slide and coverslip (37ºC). A percentage was used to represent the progressive motility.

A hemocytometer crossed with microscopic grids was used to measure the spermatozoa concentration. Sperm cells were counted in five huge squares, each counting diagonally from top left to bottom right and from top right to bottom left (Rekwot et al., 1997; Anaso et al., 2024b). Formaldehyde was utilized as a dilution reagent before counting. Using an automated pipette, a drop of semen was extracted from each sample and diluted 1:100 with formaldehyde. After mounting the hemocytometer in the microscope, a drop of the solution was pipetted into the hemocytometer chamber using an absorbable tube and an O-no pette. The outcome was noted as the sample's concentration of sperm cells.

As soon as the semen sample was collected, a smear was made using eosin-nigrosin stain to assess the live to dead sperm ratio. Using an automated pipette, a diluted drop of semen was put on a sanitized glass slide. On the slide next to the semen was a drop of the eosin-nigrosin solution. To ensure that the two samples were evenly mixed, the slide was gently turned in a circular motion. To create a thin smear on the first slide, a quarter of the portion of another clean slide was put on top of the first sample, and the two slides were carefully and gradually separated. After letting it dry, this was labeled. Each sample was then put on a microscope to count the number of living and dead sperm cells. The idea is that although active sperm cells reject the dye and stay unstained, dead sperm cells accept it and seem stained. Hancock (1951) created the aforesaid approach.

Chemical analysis

The proximate analysis of the formulated diet was done using the standard procedures recommended by association of official and analytical chemists (AOAC).

Statistical analysis

The obtained feed and nutrient intake, hematological, biochemical, semen characteristics and thermoregulation data were subjected to analysis of variance (ANOVA) in completely randomized design using the SPSS (23.0). Duncan multiple range test (DMRT) of same software was used to test the significant difference between the means at ($p \leq 0.05$ level of significance.

The statistical model is shown below

$Yij = \mu + ti + ei$

Where:

Yij = the general response to the specific parameter under investigation,

μ, the general mean peculiar to each observation,

ti = the fixed effect of the dietary treatment on the observed parameters and

ei = the random error term for each estimate

Results and Discussions

Body thermoregulation of the experimental animals

Table 2 shows body thermoregulation of experimental animals.

All the vital signs (RT, HR and RR) were not ($P>0.05$) affected by diets and were within the reference ranges of 38.5 – 39.7°C, 70 – 90 bpm and 16 – 34 cpm for RT, HR and RR respectively for healthy sheep (Merck Veterinary Manual, 2010). The results indicate the diets did not compromise normal sheep's vital signs. Generally, normal vital signs of an animal depend on recent activity, feed and water consumptions and the physiological state of the animals (Olafadehan et al. 2023; Anaso et al. 2024b; Anaso and Alagbe, 2025). The normal values obtained for the vital signs are a confirmation of the fact that the diets did not affect the body physiology and health of the

animals, suggesting that that RPCP can safely be used as a feedstuff in the diets of sheep without posing any nutritional or health challenge because lower or higher values than the normal ranges indicate physiological or health problem.

Anaso et al. (2024b) reported that respiratory rate is practical and reliable measure of the heat load and stated that respiratory rate above 25 breath per minute in small ruminant is an indicator of heat stress.

Therefore, the result obtained for heart rate, respiratory rate and rectal temperature after feeding diet containing treated cassava peel with urea-molasses ensiled with cage later droppings showed no significant difference with that of the control diet and was therefore in agreement with research conducted by Kusuma et al. (2017) who reported a non-significant (P>0.05) difference in body thermoregulatory parameters in goat feed a varying protein level on their diet.

Table 2: Thermoregulatory adaptations of the experimental animals

Parameters	Control T 1	25% RPCP T 2	50% RPCP T 3	SEM
Rectal Temp (°C)	39.48	39.49	39.56	0.35
Heart rate (bpm)	83.71	84.00	83.66	0.18
Respiratory rate (cpm)	22.59	22.82	22.85	0.17

Means in the same row are statistically different at (P<0.05), T1 indicates 0% treated cassava peel replacement, T2 indicates 25% replacement of maize with treated cassava peel, and, T3 indicates the replacement of maize with 50% of treated cassava peel, SEM: indicate standard error of the mean

HR: Heart rate, RR: Respiratory rate, EL: Ear lobe temperature, RT: Rectal temperature, TRT: Treatment, RPCP; Replacement of treated cassava peel.

Semen quality and testicular parameters of experimental animals

Semen colour was the same (creamy) for the diets. Semen pH and abnormalities were higher ($p<0.05$) in 0 and 25% RPCP than in 50% RPCP. Sperm viability was affected ($p<0.05$) in the order: 50% RPCP > 25% RPCP > 0% RPCP. Semen volume, Semen concentration, progressive motility, live spermatozoa testosterone level, scrotal length and circumference, libido test (measured as the reaction time when exposed to female) followed the same trend and was significantly highest in the 50% replacement diet compared to the 25% replacement group, with no significant difference from the control.

Semen quality evaluation is crucial since adequate fertility in livestock depends on having high-quality semen (Anaso et al. 2023; Anaso et al. 2024a; Anaso et al. 2024d). Male reproductive efficiency is actually determined primarily by sexual activity and the quality of semen (Anaso, 2024). Semen volume, concentration, progressive motility, testosterone level of living spermatozoa, scrotal length and circumference, and libido all showed parallel results, suggesting that RPCP can be added to buck diets without adversely affecting these semen characteristics. Similar semen colors in the bucks are in line with previous research on goats and rams that observed a creamy color feature (Oyeyemi et al., 2011; Ososanyo et al., 2013; Anaso et al. 2024b). Creamy white semen frequently indicates good quality, blood stains and odd hues suggest poor quality or contamination, and translucent semen typically indicates low concentration. The pH of the semen fell within Osinowo's (2016) recommended range. Greater sperm and semen EV concentrations were found in the 50% RPCP, suggesting that the diet significantly influenced spermatogenesis and improved the nutritional status of the rams while they were fed this diet. The increased availability of nutrients for the spermatogenesis process resulting from increased enhanced feed and nutrient intake (especially protein intake) may be the cause of the improved nutritional status. Although not mentioned in this study, the diet may have also enhanced ruminal microbial growth and microbial protein production (Gado et al., 2009) and nutritional digestibility (Gado et al., 2015). Improved nutrient digestibility has been shown to support the nutrition of the seminal fluid and sertoli cells that nurse the germ cells (Anaso et al., 2024b). According to Osinowo (2016), strong, progressive motility is an essential measure of sperm viability and sperm level, which may be high or low. Anaso et al. (2023) explain that motile cells are usually innately viable and viability is crucial in determining non-motile cells that are alive or dead. Therefore, the increase in sperm concentration and volume of rams on 50% RPCP signals the possibility of high fertility during service or insemination (Oyeyemi and Okediran, 2007). Diets improved and affected spermatogenesis and sperm cell viability, according to the marginal influence of diets on sperm viability (Anaso et al. 2024b). Because low-quality or inadequate food has been connected to cases of low-live sperm count, it appears that RPCP is a nutritionally acceptable feedstuff that can be added in rams' diets up to 50% without impairing semen characteristics and fertility. (Anaso and others, 2023).

In rams given diets based on pineapple waste, the sperm abnormalities in all treatment groups did not exceed the previously documented acceptable limit (Ososanya et al., 2013). In general, low quality semen is indicated by high levels of sperm abnormalities. Thus, it may be concluded that the current study found no adverse effects of nutritional therapies on semen quality. The leydig cells of the testes produce testosterone, which is essential for spermatogenesis and masculine traits. Its vascular distribution throughout the body is a significant component in male desire (Sajjad et al., 2007; Sekoni et al., 2010; Anaso et al., 2024b). Although testosterone levels were higher

at 50% RPCP than at 0 and 25% RPCP, they were still within the 2.10–10.8 ng/mL range for small ruminants in Turkey (Polat et al., 2011; Delgadillo et al., 1999), indicating that the 50% RPCP threshold level had no effect on testosterone concentration in the current study. According to Cornwall (2009), low testosterone levels are the cause of poor sperm quality because testosterone has been found to be a crucial component in the production of superior quality semen due to its favorable connection with other semen features. Given that testosterone has been shown to increase male sexual behaviour, it is possible that the higher libido (lower reaction time to doses) in the 50% RPCP is related to testosterone levels. Generally, libido (sex drive) is an important component of male fertility.

Scrotal length and circumference are important indicators when observing animals for breeding soundness. Higher SC and SL of rams fed 50% RPCP diet indicate that the diet may improve the reproductive performance and breeding soundness of the bucks. Earlier studies (Azizunnesa et al., 2013) attributed increased scrotal circumference and growth rate to nutritional plane, implying that 50% RPCP diet is perhaps nutritionally superior to the other diets.

General findings from this study were similar to results presented by Anaso et al. (2024b) who evaluated the effect of substitution of *Pleurotus ostreatus* biodegraded sugarcane scrapings (BSS) for corn bran on the growth performance and reproductive potential of Kano Brown bucks and concluded that that up to 30% biodegraded sugarcane scrapings can be used in a complete diet for bucks without negatively impacting final body weight and semen quality.

Table 3: Semen quality and testicular parameters of experimental animals

Parameters	Control T 1	25% RPCP T 2	50% RPCP T 3	SEM
Semen colour	Creamy	Creamy	Creamy	
pH	6.56[a]	6.52[a]	6.21[b]	0.07
Ejaculatory volume, mL	0.24[b]	0.26[b]	0.38[a]	0.02
Progressive motility, %	74.59[b]	75.58[b]	85.49[a]	0.77
Sperm viability, %	78.67[c]	81.33[b]	88.00[a]	3.03
Sperm concentration, x 10^6	335.92[b]	354.96[b]	396.37[a]	8.40
Live spermatozoa, %	71.32[b]	73.11[b]	85.78[a]	1.20
Sperm abnormalities, %	16.39[a]	15.63[a]	10.03[b]	0.36
Testosterone, ng/mL	2.89[b]	3.26[b]	4.06[a]	0.22
Libido, seconds	12.21[b]	12.51[b]	15.92[a]	0.33
Scrotum length, cm	10.80[b]	11.01[b]	13.11[a]	0.46
Scrotum circumference, cm	17.45[b]	17.72[b]	18.66[a]	0.29

Means in the same row are statistically different at ($P<0.05$), T1 indicates 0% treated cassava peel replacement, T2 indicates 25% replacement of maize with treated cassava peel, and, T3 indicates the replacement of maize with 50% of treated cassava peel, SEM: indicate standard error of the mean

Conclusion

The result shows that animals fed with 25% and 50% replacement of urea-molasses treated cassava peel ensiled with caged layer droppings showed no significant difference in the heart rate, respiratory rate, earlobe temperature and rectal temperature when compared with that of the control diet. It can be concluded that the different treatments had no effect on the physiology of the animals. The result shows that animals fed with 50% replacement of urea-molasses treated cassava peel ensiled with caged layer droppings gave the highest semen motility, semen live, semen concentration, semen volume, scrotal length, scrotal circumference and libido. It can be concluded that the feed containing 50% replacement of urea-molasses treated cassava peel ensiled with caged layer droppings is best for the animals as it falls within general recommended ranges.

Recommendation

Based on the finding of this study, the feed containing 50% replacement of urea-molasses treated cassava peel ensiled with caged layer droppings is recommended for diet for ruminant as it does not have any side effect on the physiological response and reproductive performance of the animals.

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Extraction of Essential Oil from Sour Orange (*Citrus aurantium*) Peels and Evaluation of its Physico Chemical Characteristics

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Abstract

The present work was carried out to obtain essential oil from the sour orange peel (*Citrus aurantium*) which is rich in essential oil through steam distillation. Extraction using distilled water was the control treatment and other treatments were carried out by using 3%, 5%, and 7% $NaHCO_3$. This study determined the yield% of essential oil in four different treatments in freshly extracted essential oil. The Physico-chemical properties of essential oil were determined in freshly extracted essential oil .In performance, T3 (5% $NaHCO_3$) was the best yield% (w/w) with a value of 3.15%. According to this study, using $NaHCO_3$ for essential oil extraction from sour orange peel resulted in a higher essential oil yield than distilled water. The extracted essential oil in sour orange peel has distinct pale yellowish color with a fresh and tangy smell. T3 exhibited that distinct color and odor. Based on the yield% and Physico-chemical analysis, the essential oil extraction using 5% $NaHCO_3$ was the best treatments followed by treatment 4 (7% $NaHCO_3$), treatment 2 (3% $NaHCO_3$) and treatment 1.

Key Words: *Sour orange peel, Extraction, $NaHCO_3$, Essential oil*

Introduction

Fruits with nutraceutical and medicinal properties are gaining importance in the modern food industry. Among many fruit trees, Citrus is an extremely important bearing genus in this regard. It includes well-known species like orange, lime, mandarin, and lemon, as well as many other underutilized species. Oranges are among the most popular fruit in the world due to their pleasant taste (Nguyen *et al*., 2009), as well as their nutritional value. So, orange fruits have long been part of the human diet due to their nutritional and medicinal properties.

A large amount of wet solid waste is generated because of the widespread consumption of orange juice. Orange juice is one of the popular beverages today. About 50-60% of the processed fruits are converted into citrus peel, which is made up of peels, seeds, and membrane residues. Fruit waste is increasing dramatically as the production of processed fruit juice increases (Garg, 2017). Orange peels are discarded inside waste containers even in homes because people prefer the orange pulp for its juicy pulp and discard the peel because it does not taste as good as the pulp. Furthermore, citrus waste is disposed of in a variety of ways. Waste discharged into lakes may cause pollution and extinction of aquatic life, especially if the body of water is insufficient to dilute the waste properly (Sharma *et al*., 2017).

This waste is caused to pollute the environment if not properly handled. That waste may affect both economic and environmental problems such as high transportation costs, lack of dumping sites, and accumulation of high organic content material (Tripodo *et al*., 2008). As a result, it is critical to treat citrus waste in food industries and other areas in a systemic manner. By producing by-products from these wastes, they can be effectively disposed. This waste primarily consists of orange peels. The peels have numerous oil-producing glands that contain significant amounts of citrus oil (Lota *et al*., 2000). As a result, rather than discarding these peels as solid waste, they can be used to extract oil (Virot *et al*., 2008).

Citrus essential oils have gotten the most attention because of their broad-spectrum insecticidal, antibacterial, and antifungal properties, as well as their high yields, aromas, and flavors (Bora *et al*., 2020). Citrus fruits have a high nutritional value, as well as high levels of elemental bioactive compounds, such as phenols, flavonoids, limonoids, essential oils, and vitamins, particularly vitamin C and carotenoids, which have numerous health benefits. These components give this fruit its distinct flavor and aroma, resulting in a more balanced and tasty diet. Above all, citrus is beneficial in the treatment and prevention of many diseases.

Citrus fruits are high in essential oils as well as other nutrients like vitamin B9, vitamin C, potassium, flavonoids, coumarins, pectin, and dietary fibers (Bora *et al*., 2020). Citrus peel oil was chosen for extraction because it has a high potential for further commercialization. Essential oils are aromatic compound mixtures that are widely used in perfumes, food, pharmaceutical, and other industries. Essential oils are primarily composed of monoterpene hydrocarbons, sesquiterpenes, and their derivatives such as esters, alcohols, and aldehydes (Toan *et al*., 2020).

Citrus essential oil also has antibacterial, antifungal, and insecticidal properties (Burt, 2004). Essential oils from citrus peels are very complex matrices composed of many compounds of various chemical classes that are primarily separated into two parts: the volatile part and the non-volatile part. Essential oils are liquids that are clear and rarely colored, and they are soluble in organic solvents that have a lower density than water (Palazzolo *et al*., 2013).

All citrus trees belong to the genus Citrus, the family Rutaceae. Bitter ("sour") oranges refer to *Citrus aurantium* L. and are hybrid between *Citrus maxima* (Pomelo) and *Citrus reticulate* (Mandarin). This plant is native to southeastern Asia (Anwar *et al*., 2015). *Citrus aurantium* is a Latin name for bitter orange (Moonaz *et al*., 2010). Bitter orange is well-known for its use in the treatments of anxiety, lung, and prostate cancers, gastrointestinal diseases, and obesity. *Citrus aurantium* essential oils contain bioactive compounds with antimicrobial, antioxidant, anti-inflammatory, and anti-anxiety properties (Kacaniova *et al*., 2020).

Bitter orange consists of large amount of active constituents. Those active constituents can be found in bitter orange juice, flowers, seeds, leaves as well as peels. Active constituents in bitter oranges provide many biological effects, such as antioxidant, antimicrobial, anti-cancer, anti-diabetic, etc (Maksoud *et al*., 2021). Other than therapeutic applications, *Citrus aurantium* is used in the food production industry also. The food applications of bitter oranges are *Citrus aurantium* juices, wines, jams, canned fruits, and dried fruits. Those various applications of *Citrus aurantium* fulfill the better utilization of bitter orange and thus extend its industrial chain. The development of those value-added bitter orange products can partially overcome the defects of seasonality and the short life of fresh bitter oranges, and meet the nutritional requirements of novel fruit products from consumers (Liu *et al*., 2022).

The essential oil was extracted from citrus peel by using different methods such as steam or hydro distillation, maceration, solvent extraction, soxhlet extraction, cold pressing, supercritical fluid extraction, microwave-assisted extraction, etc. Those extraction methods can be divided into two types. They are traditional extraction methods (conventional methods) and non-conventional extraction methods. Conventional methods, which use organic solvents, necessitate long extraction time, large amount of energy, and other resources, posing as much of an environmental risk (Chemat *et al*., 2019) as the biodegradable properties of citrus waste already do. Because of the drawbacks of traditional extraction methods, the wide availability of citrus waste, and the emerging need to reduce environmental impact, there has been an increase in interest in the responsible management of this type of waste (Da *et al*., 2018). Furthermore, non-traditional technologies known as "green extraction methods" has gained importance. These are the most sustainable methods for obtaining bioactive compounds from citrus residues, allowing for better resource utilization. Their main advantages are improved performance, lower energy, time, and other resource expenditure, and the use of few or no organic solvents (Anticona *et al*., 2020).

Materials and Methods

Preparation of Sour Orange peel sample

The Sour Oranges were washed with clean water and peeled thinly. Thin outer peels were cut into small square shape cubes. Then those peels were ground into formed a fine particles of peels without drying.

Prepared Sour Orange peel sample transferred into the Extraction

Kjeldahl apparatus was used for the extraction of essential oil from sour orange peels fine particles.

Extraction of Essential oil with different treatments

The essential oil was extracted by using four different treatments. After the sample was transferred into the 500 ml flat bottom flask, the flask was connected to the Kjeldahl apparatus. 50ml graduated cylinder was used as the receiver. Then the mixture was distilled rapidly by heating it to 180ºC for 2 hours. The steam was generated from the boiling water (as the flask was heated) the volatile oil was extracted which was condensed as part of the steam into the distillation flask as it was passed through the cooling system.

T1 – Extraction with Distilled water (control): 150g sour orange peel particles + 250 ml distilled water
T2 – Extraction with 3% $NaHCO_3$: 150g sour orange peel particles + 7.5g $NaHCO_3$
T3 – Extraction with 5% $NaHCO_3$: 150g sour orange peel particles + 12.5g $NaHCO_3$
T4 – Extraction with 7% $NaHCO_3$: 150g sour orange peel particles + 17.5g $NaHCO_3$

Separation of Essential oil

The distillate (a mixture of oil and water) was poured into a separating funnel where the mixture separated into two layers. Then 10ml of n-hexane was added into the separating funnel and the stopper was placed. Then the separating funnel was shaken while releasing the pressure that may form in the funnel constantly. After that funnel was let into a stand for a 5 minutes for clear separation. The stopcock of the funnel was opened and the aqueous phase was drained into a 100ml Erlenmeyer flask. The stopcock was closed when the organic phase reaches it and it was recovered into a separate container. The process was repeated for twice using 5ml of n-hexane. Then needed to evaporate the hexane which in the beaker to isolate the oil using water bath. It was begun to evaporate at about 62.5 ºC. Finally, the thermometer was placed in the solution to monitor if it is hexane left or not. If the thermometer reached more than 80 ºC so then decide to stop evaporation. The extracted pure essential oil was placed in an airtight bottles.

Characterization of the Essential Oil

After the oil was extracted, it was characterized to ensure that the extracted liquid was indeed oil. The essential oil extracted from Sour Orange peels under optimal processing conditions was characterized by determining the physico-chemical properties.

Statistical Analysis

Each formulation was replicated in experiments and they were in Complete Random Design (CRD). Analysis of Variance (ANOVA) (α=0.05) and mean separation was done with Turkey's studentized test. Physio-chemical analysis and storage studies were done through Minitab 17 software statistical package

Results and Discussion

The Yield of Extracted Essential Oils from Sour Orange Peel Samples

Table 1 Yield % of freshly extracted essential oil samples

Treatment	Yield %(W/W)
T1	1.46 ± 0.22^{c}
T2	2.09 ± 0.01^{b}
T3	3.15 ± 0.04^{a}
T4	2.52 ± 0.04^{b}

The values are means of the triplicates ± standard error.
Means values with the same letters within the same column do not differ significantly at 5% level.

According to the results, essential oil yield % was high in the T3 (5 % $NaHCO_3$) treatment. The maximum essential yield was 3.15%. Mainly essential oil yield % was less in the first treatment which the extraction was done using distilled water. That yield was 1.46%. When the $NaHCO_3$ percentage was increased from 3% to 5%, the essential oil yield% also increased, but again at T4 (7% $NaHCO_3$), the oil yield % was decreased than T3.

Color

The color was determined by observing the samples visually. T1 (control) and T3 (5% $NaHCO_3$) essential oil samples were pale yellowish-white in color. T2 (3% $NaHCO_3$) and T4 (7% $NaHCO_3$) essential oil samples were pale reddish brown in color.

Odor

All treatments, T1, T2, T3, and T4 were given a fresh and tangy smell.

Solubility

In all treatments, T1, T2, T3, and T4 essential oil samples were insoluble in water.

Chemical Characteristics of Freshly Extracted Essential oil

The chemical characteristics of extracted essential oil such as saponification value, acid value, free fatty acid value, ester value, pH, and refractive index of the freshly extracted essential oil revealed there was significance difference between the treatments of essential oil at 5% level of significance.

Table 2 Chemical characteristics of freshly extracted essential oil samples

Treatment	Saponification value (mg KOH/g)	Acid value (mg KOH/g)	Free fatty acid content (mg KOH/g)	Ester value (mg KOH/g)	pH	Refractive index
T1	24.52±0.20^{d}	4.10±0.06^{a}	3.06±0.05^{a}	20.42±0.21^{d}	6.76±0.01^{c}	1.35±0.006^{a}
T2	41.54±0.17^{c}	3.87±0.03^{b}	2.43±0.07^{b}	37.67±0.14^{c}	6.97±0.07^{c}	1.25±0.006^{b}
T3	42.67±0.11^{b}	3.47±0.03^{c}	2.09±0.02^{c}	39.19±0.14^{b}	7.27±0.08^{b}	1.21±0.006^{c}
T4	44.57±0.21^{a}	3.07±0.04^{d}	1.94±0.003^{c}	41.49±0.21^{a}	8.12±0.003^{a}	1.02±0.006^{d}

The values are means of the triplicates ± standard error
Means values with the same letters within the same column do not differ significantly at 5% level.

While increasing the $NaHCO_3$ concentration from 3% to 7% for essential oil extraction, the saponification value of freshly extracted essential oil from sour orange peels was increased from 41.54 mg KOH/g to 44.57 mg KOH/g. when the $NaHCO_3$ concentration was raised from 3% to 7%, the acid value of the extracted essential oil decreased from 3.87 mg KOH/g to 3.07 mg KOH/g. According to the results, treatment 1, which extraction of essential oil using distilled water, contains the least mean ester value (20.42 mg KOH/g). The mean ester value of treatments 2, 3, and 4 were found as 37.67, 39.19, and 41.49 mg KOH/g respectively
According to the results, pH value (Figure 4.6) was high in T4 (7% $NaHCO_3$) essential oil. The highest mean pH value is 8.12. pH value was less in T1 (control) than in others. The least pH value is 6.76. pH value was increased, when increasing $NaHCO_3$ concentration from 3% to 7%. According to the results, mean value of refractive index was high in treatment 1 (control). The least refractive index was in treatment 4 (7% $NaHCO_3$).

Conclusion

The results of this particular study revealed that in the extraction of essential oil using steam distillation, the highest yield % of essential oil was obtained from T3 (5% $NaHCO_3$), 2 hours of distillation in sodium carbonate, therefore, the concentration of $NaHCO_3$ aids in the extraction of essential oil from the plant tissues of the sour orange peel. This research revealed that using $NaHCO_3$ for essential oil extraction, provided a higher yield than using distilled water. According to the results, the yield % was increased in the following manner. That is, T1<T2<T4<T3.Based on chemical characteristics, saponification value was increased according to T1<T2<T3<T4, 123.48mg KOH/g, 151.95mg KOH/g, 164.9mg KOH/g, 170.33 mg KOH/g respectively. Ester value was high in treatment 4 (7% $NaHCO_3$). Treatment 1 had the highest mean value for acid value and free fatty acid content than other treatments. Based on the Yield %, physical and chemical, the essential oil extraction using 5% $NaHCO_3$ was the best treatment compared to other treatments.

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Nutritional Composition of Hass Avocado (*Perseaamericana* Mill) Cultivated in Major Growing Areas in Kenya

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Abstract

Avocado is an important horticultural crop in Kenya and a key export fruit. The quality of avocado fruit is influenced by numerous environmental factors such as soil composition, elevation, rainfall, temperature, and sunlight exposure, alongside crop husbandry, postharvest handling, and geographical origin. Avocado samples from these regions were analysed for proximate composition, including ash, protein, lipid, fibre and carbohydrates, and fatty acid composition of extracted oils.

Findings revealed marginal variations across the regions. In terms of weight, samples from Nandi were the highest with 231.85 ± 0. 84g, followed by Kisii (219.52 ±0.59g), Muranga (165.02 ±0.94g) and Nakuru (149.20 ±1.35g), respectively. Moreover, samples from Murang'a recorded the lowest pulp yield (62.28%) and the highest seed proportion (23.08%), while other regions showed an insignificant difference in pulp content (71.33%) and seed (14.48%). The pulp content of Murang'a and Nandi regions exhibited the highest fat content at 68.26±3.18% (dwb) and 64.22±0.93% (dwb), followed by Kisii at 60.84±0.31 % (dwb). Nakuru had the lowest lipid content at 45.91% (dwb). Samples from Kisii had higher ash content (6.79% dwb), those from Murang'a had elevated fibre (4.46% dwb), while samples from Nakuru exhibited higher protein (7.63%dwb) and carbohydrate (36.61% dwb) levels. The fatty acid composition of avocados was in the range of oleic acid 55.1-60%, followed by Palmitic acid 22.1-23.8%, Linoleic was 18.8-21.1%, with saturated/unsaturated ratio in the range of 0.27-0.31, implying healthy fatty acid profiles for human nutrition for all the samples. Generally, the quality of the study samples was comparable to those traded globally in terms of nutrient profile.

Overall, Kenyan Hass avocados meet the required export quality in terms of size (calibre), pulp-to-seed and peel ratio was within acceptable limits, the nutritional composition of avocados and their lipid content is in line with those reported in key avocado-producing and exporting countries.

Keywords: *Hass avocado; proximate composition; Fatty Acid profile; lipid quality; Kenya*

Introduction

Avocado consumption has increased globally over the past years due to its recognised nutritional benefits, particularly its rich content of monounsaturated fatty acids (MUFAs), protein, vitamins, minerals, and dietary fibre (Acosta-Díaz et al., 2019; Carvajal-Zarrabal et al., 2014). The fruits are a good source of folate, potassium, healthy fats, and vitamins K, C, and E, and also contain small amounts of B vitamins and minerals, such as copper, phosphorus, magnesium, manganese, iron, and zinc (Ford et al., 2023). The monounsaturated fats in avocados, most of which are oleic acid, are good for heart health, fight inflammation, and may have anticancer properties (Carvalho & Velásquez, 2015; Méndez Hernández et al., 2023)

Kenya is a significant player in avocado production and export and is currently ranked 5th in avocado production after Mexico, Colombia, Peru and the Dominican Republic (FAO, 2024). In 2018, for instance, a total of 318,087,000 kgs of avocado fruit was produced in Kenya, with the Central region accounting for 54.4%, Eastern (9%), Western (3.3%), Rift Valley (7.4%), Nyanza (21%), Coast (2.9%) and Nairobi (2%). The major avocado-producing counties in Kenya are Murang'a (42%), Kiambu (11%), Kisii (7%), and Nyamira (5%), while Bomet, Embu, Meru and Bungoma account for 3% each (MoALFD, 2020). The country is ranked 6th in avocado export globally and 1st in Africa. Moreover, Kenya is ranked 3rd after Israel and Mexico among avocado exporters to the European market, with the Netherlands, U.A.E., France, UK, and Saudi Arabia being the five largest importers of Kenyan avocados (MoALFD, 2020).

The main avocado varieties grown in Kenya are Hass (20%) and Fuerte (80%) for the export market and Puebla, Duke and G6 for the domestic market (Mellado& Ferrari, 2019). Hass avocado is regarded as the most important in terms of cultivated area, geographical distribution and consumption(Cruz-lópez & Caamal-cauich, 2022; USDA, 2018). It is the most popular export variety because it enjoys a big market in Europe and other destinations compared to the other varieties (Kathula, 2021). Moreover, the variety has gained particular prominence due to

international demand fuelled by its perceived health benefits, unique flavour and extended shelf life (Nyakang'i et al., 2023).

While avocado export is key to Kenya, the sector faces myriad challenges; hence, many harvested fruits do not meet export quality standards. Approximately 45% of the fruits are not export quality and provide raw materials for oil extraction. Avocado oil processing is enjoying phenomenal growth in Kenya and provides a growing market opportunity for Grade 2 avocados unsuitable for export or sale in the domestic fresh fruit market (USAID, 2018). Domestic demand for Kenyan avocados accounts for more than 80% of total production, with the remainder exported as fresh fruits or processed and exported as crude oil (Kathula, 2021).

The quality of avocado fruit is influenced by numerous environmental factors, such as crop husbandry, postharvest handling, and geographical origin (Juan Camilo et al., 2019). Varied soil composition, elevation, rainfall, temperature, and sunlight exposure create distinct micro-environments influencing nutrient uptake by avocado trees, impacting the accumulation of essential nutrients, antioxidants, and bioactive compounds in the fruit (Kenbon Beyene, 2017; Ramírez-Gil et al., 2019). Such disparities can lead to differences in macronutrients, micronutrients, and antioxidants in avocados, with those grown in favourable environments offering enhanced nutritional quality and potential health advantages for consumers. Moreover, regional disparities may also influence the taste, flavour, and texture of fruits and can be attributed to differences in the composition of sugars, organic acids, and volatile compounds (Mccarthy & Considine, 2008). The sensory attributes and nutritional composition contribute to consumer preferences and market demand for avocados.

Previous research has delved into several aspects relating to avocados. For instance, a study in Egypt (Rozan et al., 2021) examined various avocado varieties' chemical composition, bioactive compounds, and antioxidant activity. Another study conducted in Malaysia focused on the proximate composition and physical properties of Thompson red avocado fruit (Tan et al., 2022). In Colombia, Henao-Rojas et al. (2019) explored the influence of different growing regions on avocado quality. In Kenya, research on the total phenolic content of avocado seeds was reported (Githinji et al., 2013), but studies profiling its nutritional composition are largely lacking despite Hass avocado's significance in the country. Furthermore, the influence of different growing regions on the nutritional composition of Hass avocado remains unexplored. Existing studies have suggested that climate and ecological variations, including geographical location and agricultural practices, can affect avocado composition, highlighting the necessity to evaluate this aspect concerning Hass avocados in Kenya.

Avocado is consumed in various forms in Kenya and globally, as puree salads, juice, seasoned with salt. Avocado pulp contains from 67 to 78% moisture, 13.5 to 24 % lipids, 0.8 to 4.8% carbohydrate, 1.0 to 3.0% protein, 0.8 to 1.5% ash, 1.4 to 3.0% fiber, and energy density between 140 and 228kcal (Duarte et al., 2016). Avocado

The country’s diverse regions exhibit significant geographical and climatic variations, which profoundly affect the growth of crops (Henao-Rojas et al., 2019; Kathula, 2021; Nyakang'I et al., 2023). This study aims to investigate and compare Hass avocados' nutritional composition and fatty acid profile from major producing regions in Kenya.

Materials and Methods

Study site

The study was conducted in Murang'a, Nakuru, Kisii, and Nandi Counties of Kenya. Among these, Murang'a County was the primary contributor to avocado production, accounting for 31% of the total value of Kenya's top 10 avocado-producing regions. This percentage represents the broader Central Kenya counties engaged in avocado cultivation. Kisii follows, with 6.8%, representing regions in Nyanza and South Rift involved in avocado production. Nakuru produced 6.8%, representing the avocado-producing counties in the Central Rift Valley.

Meanwhile, Nandi County contributes 2.7%, representing Western Kenya and North Rift in avocado cultivation. These counties lead in their regional avocado production in Kenya. Furthermore, the combined avocado production from these counties accounts for 47.9% of the national avocado production in value (MoALFD, 2020).

Study Design

A quantitative descriptive comparative study design was employed for the investigation. This design enabled the simultaneous collection and assessment of data across multiple distinct avocado growing areas within Kenya.

Sample collection

Representative samples of Hass avocado were collected from the study regions, with four avocado farms selected per county to represent each area. Only farms with Global GAP Certification were selected in the study. One hundred sixty (160) mature Hass avocados were randomly collected from different trees within the farms based on Codex standard 197-1995. The selection criteria ensured uniformity in maturity, size, and the absence of visible defects among the avocados. All samples were transported to Kenya Industrial Research and Development Institute (KIRDI) and Spectre Laboratories under controlled temperature and humidity conditions to maintain freshness and integrity. Ripening of the avocados was conducted at 20°C, and sample analyses were performed when the avocados ripened.

Sample preparation

The sample preparation involved cleaning and careful extraction of pulp, seed, and peel from the Hass avocado obtained from each region. The samples were carefully washed and then split to access the pulp, seed, and peel.

The peel, pulp and seeds were manually separated, with the seeds extracted and cleaned. Subsequently, each farm's pulp, seed, and peel were aggregated separately to form representative samples. The aggregated components were weighed and prepared for analysis. The fruit parts were cut into smaller pieces and dried in an oven dryer (Memmert, Germany) for three days at 45 ºC. The dried fruit parts (moisture content 9%) were ground into powder using a home blender (Waring MX1500XTX, USA). The powdered samples were stored in airtight plastic containers at -20 ºC until further analysis.

Mass and calibre of fruits

The whole fruits and fruit parts (peel, pulp, and seeds) were weighed using a digital balance (Shimadzu AUW220D, Japan), and the results were expressed as a percentage of total mass.

Proximate Composition Analysis

The proximate composition analysis was carried out to assess the nutrient content of the avocado samples. This analysis encompassed the quantification of essential components, including carbohydrates, proteins, calorific value, total ash content, fibre, and fats, employing established standard analytical methods outlined by the AOAC (Association of Official Analytical Chemists). Total ash content was assayed by placing the sample in a muffle furnace at 550°C for 8 hours (AOAC 942.05, 2012). The protein content was evaluated using the Kjeldahl method (N x 6.25) (AOAC 960.52, 2012), while crude fibre content was quantified following the AOAC method 2009.01, and fat content determined by solvent extraction method (AOAC 2003.06-2012) (AOAC, 2012). Carbohydrate content was obtained by difference, involving the subtraction of the combined weights of moisture, protein, fat, ash, and fibre from the total sample weight. The data obtained were expressed as percentages on a dry weight basis (dwb).

Fatty Acid Composition Analysis

Near-infrared (NIR) spectroscopy was employed to analyse lipid profiles. This method harnesses the near-infrared region of the electromagnetic spectrum, spanning approximately 700 to 2500 nanometres. By assessing the light interactions involving a sample, NIR reflectance spectra can swiftly unveil the material's properties without requiring sample modification. This approach is facilitated by the fact that NIR absorption bands, at wavelengths around 1600–1800 nm and 2100–2200 nm, correspond to distinct features in the molecule, specifically the straight carbon chain and double bonds, respectively.

Statistical Analysis

The data collected were analysed to obtain means and standard deviation for avocado samples from selected regions in Kenya. Analysis of variance (ANOVA), followed by a post-hoc test, was conducted to establish significant differences ($p < 0.05$) among samples from different regions. Data was analysed using GraphPad Prism 8 (GraphPad Software, Boston, MA-USA).

RESULTS AND DISCUSSION

Hass avocado calibre and weight of fruit and fruit parts from selected regions in Kenya

The weight of Hass avocado fruit samples exhibited varied results depending on the sampled region, as shown in Table 1 below. Fruit samples from Nandi were the heaviest with an average weight of 231.85 ± 0. 84g, followed by Kisii (219.52 ±0.59g), Muranga (165.02 ±0.94g) and Nakuru (149.20 ±1.35g), respectively. Based on calibre ranking, the Hass avocado samples from Murang'a had a calibre of 24, while Nakuru, Kisii and Nandi recorded values of 26, 18 and 16, respectively. This grading system is based on United Nations Economic Commission for Europe (UNECE) criteria for size (calibre) grading used by avocado producers and exporters, with European Union (EU) buyers preferring a calibre range of 16 (227g to 274g) to 20 (184g to 217g) (UNECE, 2019). Based on this criterion, samples from Nandi and Kisii fall within the acceptable range and hence qualify for export to Europe, while Muranga and Nakuru were not within the preferred levels.

Such variability in the weight of Hass avocado fruit has been observed in previous studies (Carvalho et al., 2014; López-Pimentel et al., 2022), where avocados from orchards in high-altitude areas had higher weights and sizes than those from lower-altitudes. Nandi and Kisii regions sit at higher altitudes (up to 2062mtrs and 2190mtrs, respectively) than Nakuru and Murang'a (1912mtrs and 1665.06mtrs, respectively). Other than altitude, factors such as soil fertility, climatic conditions and agricultural practices have also been attributed to variations in fruit sizes/weights (Henao-Rojas et al., 2019).

Table 1. Calibre and Mean weight of avocado fruit, peel, pulp and seed from selected regions in Kenya. Weight data indicates the Mean ±SD of triplicate samples.

County	Calibre	Fruit weight (g)	Pulp weight %)	Seed weight (%)	Peel weight (%)	Pulp/Seed
Muranga	24	165.02 ±0.94	62.71±0.43	22.83±0.23	13.75±0.23	2.75
Nakuru	26	149.20 ±1.35	70.87±0.24	14.32±0.22	15.41±0.26	4.95
Kisii	18	219.52 ±0.59	70.93±0.08%	16.02±0.11	13.38±0.14	4.43
Nandi	16	231.85 ± 0.84	72.66±0.16	13.61±0.175	14.00± 0.07	5.33

The percentage (%) pulp content of Hass avocado from Muranga, Nakuru, Kisii and Nandi were 62.71±0.43%, 70.87±0.24%,70.93±0.08%, and 72.66±0.16%, respectively, while the seeds accounted for 22.83±0.23%, 14.32±0.22%, 16.02±0.11%, and 13.61±0.18%, respectively. The proportion of peel, on the other hand, was 13.75±0.23%, 15.41±0.26%, 13.38±0.14%, and 14.00± 0.07%, respectively. From the results, fruits from Murang'a exhibited the lowest pulp percentage of 62.71±0.43%, compared to Nandi, which recorded the highest pulp percentage, 72.66±0.16%, while Nakuru and Kisii had no significant difference. The pulp percentage difference between the regions differed significantly ($p<0.05$), with Muranga recording a significantly lower value than the other counties. Conversely, Murang'a also showed the highest seed percentage, 22.83±0.23%, compared to the other regions, which were between 13.61±0.18and 16.02±0.11%. The seed percentage difference between the regions was significantly different ($p<0.05$). All the regions exhibited relatively similar peel percentages (Kisii 13.38±0.14%, Murang'a13.75±0.23%, Nandi 14.0±0.07%, and Nakuru 15.41±0.26 %, with samples from Nakuru being significantly higher than from the other regions ($p<0.05$). Murang'a origin avocados exhibited the lowest pulp and highest seed percentages, making them less desirable than those from Nandi, which had high pulp and low seed percentages. The observed differences can be attributed to environmental factors such as microclimate, soil fertility, climate conditions, and possibly agricultural practices specific to each region.

The present findings on pulp percentage largely fall within that was reported by (Alnasan et al., 2019), who found that Hass possesses a pulp content ranging from 67.96% to 85.3%, with Hass avocado having 67.96% in Hass, and Fortuna cultivars having 85.3% pulp content. Another study reported that avocado pulp represents between 52.9 and 81.3% of the fruit mass (Jimenez et al., 2021), while all the Hass avocados sampled in the present study fall within the range. Meanwhile, seed and skin/peel comprise about 33% of the total fruit weight (Dreher & Davenport, 2013). It was reported that, on average, an avocado fruit consists of the peel (7–15%), the pulp (65–73%), and stone (including the seed) (14–24%) (García-Vargas et al., 2020). It was reported that avocado fruits with lower seed and peel levels are most interesting for oil extraction due to their higher pulp yield (Domínguez et al., 2016). A study in Ethiopia by Tesfaye et al. (2022) established that the avocado seed represents 13–18% of the fruit, similar to our findings. Further, the seed and peel content of Hass are notably lower, making it suitable for various home consumption and guacamole and industrial applications like oil extraction. The pulp to seed ratio of avocados from Muranga, Nakuru, Kisii and Nandi were 2.75, 4.95, 4.43, and 5.33, respectively. The higher the pulp-to-seed ratio, the higher the avocado pulp yield. The distinctive proportions of seed, pulp, and peel in the Hass avocado contribute to its culinary versatility and commercial success, underscoring its significance in the avocado market. In a study reported on the Hass avocado from Ethiopia, it was established that the Hass avocado cultivar showed a greater flesh-to-seed ratio (13.57±10.43) and had a lower fruit weight (183.92±47.58g) (Kenbon Beyene, 2017).

Proximate composition of Hass avocado pulp from selected regions in Kenya

The results of the proximate composition of Hass avocado pulp are shown in **Hata! Başvuru kaynağı bulunamadı.** below. The data showed non-significant variation in the nutritional composition of the avocado pulp between the proximate parameters except for fats (% w/w) dwb and carbohydrates (% w/w) dwb. No statistically significant differences were observed at ($p < 0.05$) level. Avocados from Kisii exhibited the highest ash content of 6.79±0.53% (dwb), suggesting superior mineral content. Conversely, avocados from Nakuru demonstrated the highest protein and carbohydrate content at 7.63±0.85% (dwb) and 36.611±0.46% (dwb), respectively. In contrast, avocados from Murang'a displayed elevated fat and fibre levels, with values of 68.26±3.18% (dwb) and 4.46±0.32% (dwb), respectively.

Fat and carbohydrate content exhibited the highest levels among the proximate parameters analysed, a finding consistent with the established nutritional profile of Hass avocado (Jimenez et al., 2021). Notable parameter variations were observed among the regions, with statistically significant differences ($p < 0.05$) in lipids and carbohydrates. Specifically, Murang'a and Nandi regions exhibited the highest fat content at 68.26±3.18% (dwb) and 64.22±0.93% (dwb), respectively, whereas the lowest lipid content was reported in the Nakuru at 45.91% (dwb), and Kisii 60.84±0.31 % (dwb). Carbohydrate content for Murang'a had the lowest levels at 13.67±2.64% (dwb), contrasting with Nakuru, which displayed the highest at 36.61±0.46% (dwb). Kisii and Nandi regions reported intermediate carbohydrate levels at 21.49±0.31% (dwb) and 19.67±1.22% (dwb), respectively.

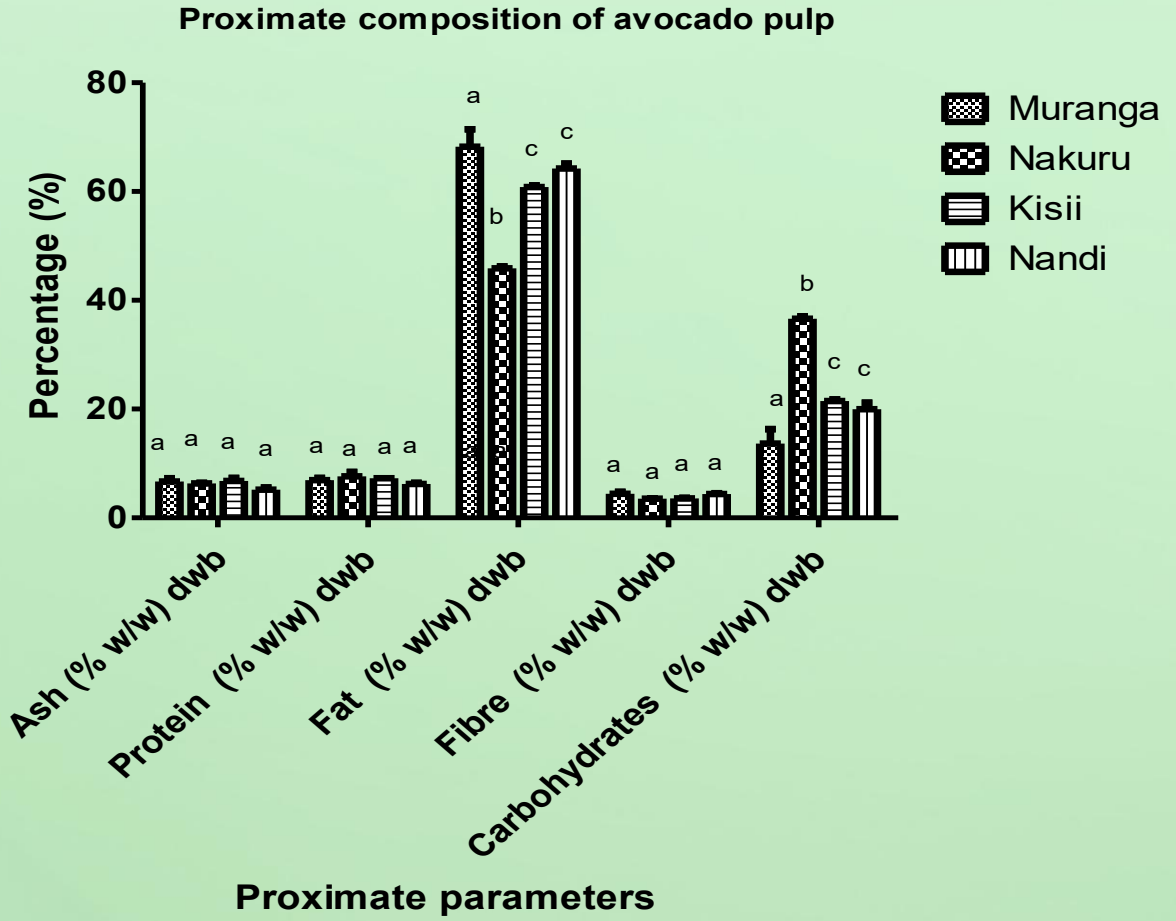


Figure 1.The Proximate composition of Hass avocado pulp. Each data point represents the mean±SD of triplicate samples. Bars with similar letters are not significantly different, while those with similar letters are significantly different at $p < 0.05$.

The avocado pulp contains high lipids content, which makes the pulp the portion of greatest interest. Avocados are among the fruits with the highest fibre content, including 75% insoluble and 25% soluble fibre (Araújo et al., 2020; Noorul et al., 2016). It was reported that the relative amount of pulp varies according to cultivar, from 67.96% in Hass to 85.3% in the Fortuna cultivar. The oil content may also vary widely (13.15% in Margarida to 25% in Hass) by soxhlet extraction and (7.9% in Margarida to 20% in Hass) by cold-centrifugal (Alnasan et al., 2019). A study on Mexican avocado pulp reported the following values: carbohydrates (4.2–5.6%), proteins (1.2–1.8%), dietary fibre(12.55–15.8%), and lipids (12– 16%) on a wet weight basis (Méndez-Zúñiga et al., 2019). Other studies report moisture content ranging from 67 to 78%, lipid content ranging from 12 to 24 %, carbohydrate content ranging from 0.8 to 4.8%, protein content ranging from 1.0 to 3.0%, ash content ranging from 0.8 to 1.5%, fibre content ranging from 1.4 to 3.0%, with energy of between 140 and 228 kcal per avocado on wet weight basis (Duarte et al., 2016).

Fatty Acid profile of Hass Avocado from selected regions in Kenya

The oleic content of Hass avocado was in the range of 55.1-60%, followed by Palmitic acid 22.1-23.8%, Linoleic was 18.8-21.1%, with only Nandi origin samples having trans fatty acid in negligible level of 2% as, while the Linolenic and stearic acids were largely below the detection limit per Figure 2 the results within the range of reported values for Mexican avocados (Méndez-Zúñiga et al., 2019). Moreover, the results largely conform to the proposed Codex Standard for avocado oil profile, which specifies that Palmitic acid C16:0 is 11.0–26.0%, Linoleic acid C18:2 (7.8–19.0%), Oleic acid C18:1(42.0–75.0%), and C18:3 Linolenic (0.5–2.1 %) (Green & Wang, 2023). A study on 68 avocado oil samples in the USA found the following values: C16:0 9.90–23.19%, C16:1 3.32–10.03%, C18:1 49.74–71.41%, and C18:2 9.25–22.46% (Green & Wang, 2023). According to a study by Méndez Hernández et al. (2023), the fatty acid profile of avocado is within the following arrange: oleic acid represents 50–60% of the total fatty acids, followed by palmitic (15–20%), palmitoleic (6–10%), linoleic (11–15%), and linolenic (1%) acids. Thus, monounsaturated fatty acids dominate the composition of avocado oil, especially oleic acid. A study to determine the effect of altitude on orchards of avocados found that the quantities of oleic acid decreased drastically at lower altitudes while the amounts of palmitoleic and linoleic

acids increased (Carvalho & Velásquez, 2015). Therefore, this can explain slight variations in amounts across the sampled regions. Another study found that exposure to the sun increased the proportion of the saturated fatty acid palmitic acid and decreased the proportion of monounsaturated fatty acid oleic acid (Woolf et al., 1999). Palmitic acid levels were the highest of the saturated fatty acids in all samples, ranging from 38.37% to 48.32% of the total lipid. The oleic acid content in all avocado cultivars was higher than those of other unsaturated fatty acids. It was further revealed that early and late-harvested fruits showed higher total lipid content than the rest (Teng et al., 2016). Moreover, a study of 12 native Mexican avocado accessions found that the primary saturated fatty acids in all the avocado accessions were palmitic acid (15.54-22.68%), monounsaturated fatty acids (oleic) (56.58-74.19%) while polyunsaturated fatty acids were linoleic (5.62-16.85%), and linolenic (0.63-2.85%) being the most abundant unsaturated fatty acids in all the accessions (Méndez-Zúñiga et al., 2019). Researchers in Colombia determined that at a higher elevation, the concentration of fatty acids in avocados increases (Ramírez-Gil et al., 2019).

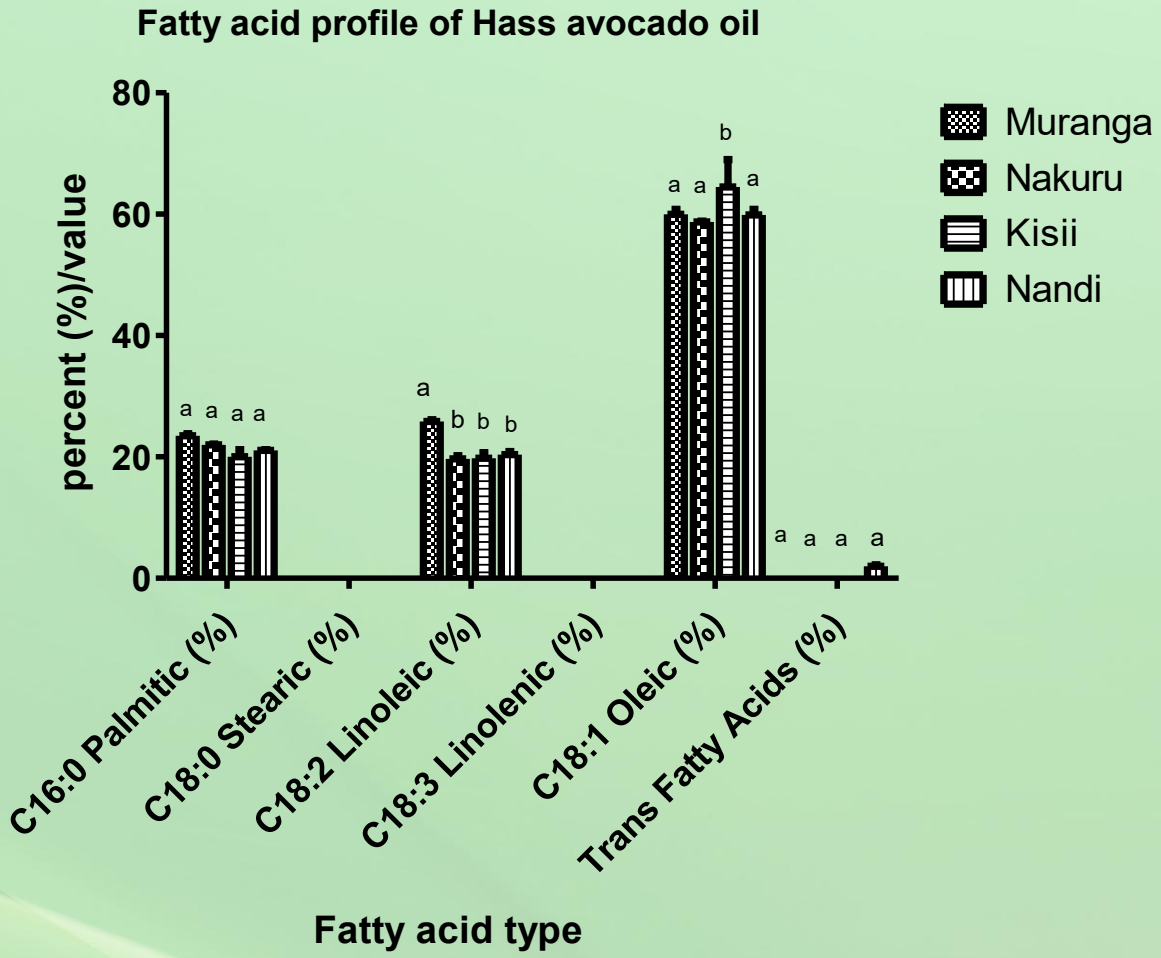


Figure 2. Fatty acid profile of Hass avocado oil. Each data point represents the mean±SD of triplicate samples. Bars with similar letters are not significantly different, while those with similar letters are significantly different at $p < 0.05$.

Previous publications reported Hass avocado pulp composition to be as follows: oleic acid (18:1n-9) (about 59%), Palmitic acid (16:0) (approximately 14%), linoleic acid (18:2n-6) is the predominant polyunsaturated fatty acid (approximately 11%) (Ford et al., 2023). The fatty acid profile is influenced by ripening, where during ripening at 20 ◦C, palmitic acid content decreases and polyunsaturated fatty acids increase, while monounsaturated fatty acids remain relatively unchanged. However, pre-harvest conditions may influence fatty acid profiles because lower growing temperatures shift the oil profile towards more oleic acid and less palmitic acid (Ferreyra et al., 2016; Ozdemir & Topuz, 2004). These regional fat and carbohydrate content disparities may be linked to origin, season, and production practices (Rodríguez et al., 2023).

It was reported that harvesting time affects the lipid content of avocado fruit. Early and late-harvested fruits showed higher total lipid content than others (Teng et al., 2016). The MUFAs essentially consist of Oleic acid, the predominant monounsaturated fat in avocado oil, making up approximately 60-70% of the total fatty acids. Oleic acid is a heart-healthy fat that has been associated with various health benefits. Meanwhile, for saturated fatty acids, palmitic acid is the primary saturated fat found in avocado oil, comprising around 15-20% of the total fatty

acids. Of the polyunsaturated fatty acids (PUFAs), Linoleic, an omega-6 fatty acid, is the primary constituent but occurs in low amounts in avocado oil. However, the exact proportion may vary. It is important to note that the specific fatty acid composition can differ slightly based on factors such as avocado variety and growing conditions. However, Hass avocados from Mexico, one of the major producers of avocados globally, generally exhibit a similar fatty acid profile (Rodríguez et al., 2023). Oil may be classified as hard or soft, depending on the ratio of saturated to unsaturated fatty acids. Soft oils are defined as liquid oils containing a very high percentage of unsaturated fatty acids, while hard oils contain high levels of saturated fatty acids (Naghshineh et al., 2010).

Table 2.The Fatty acid quality of Hass avocados from the four (4) main avocado-producing regions in Kenya.

Region	**Total saturated fatty acid**	**Total Saturated fatty acid**	**Saturated/Unsaturated fatty acid ratio**
Muranga	23.8	76.2	0.31
Nakuru	22.1	77.9	0.28
Kisii	21.2	78.8	0.27
Nandi	21.2	78.8	0.27
Average value			**0.28**

The desirable ratio is between 0.1-0.44, with lower values representing the best oil/fat quality. This signifies that the fatty acid profile of the Kenyan avocado is healthy, with samples from Kisii and Nandi having the best ratio. The values of Kenyan Hass avocado oil were within the range reported for various avocado-producing countries as per a study report on the saturated/unsaturated ratio reported that Australia 0.35, Mexico 0.29, New Zealand 0.26, USA 0.30, and Colombia 0.2 (Ramírez-Gil et al., 2019). The findings are within the ratios reported in avocados from Morocco, where Hass avocado oil was rich in oleic, palmitic, linoleic, and palmitoleic acids, while stearic acid was present in low amounts. The Reed variety had the highest amount of oleic acid (61.18%) among all studied varieties (Nasri et al., 2021). A previous study (Bob Bergh, 1992) reported that linoleic acid was slightly above 21%, which agrees with the present findings of Hass avocado of 26.1-21.8%. Increasing polyunsaturated (PUFA) intake lowers LDL-C and decreases heart disease risk; increased PUFA intake lowers LDL-C by increasing LDL receptor activity (Teng et al., 2016; Weschenfelder et al., 2015).

Conclusion

This is one of the pioneer studies on the nutritional profile of Hass avocados in Kenya. The study revealed that the size of Kenyan avocados and the pulp, seed, and peel content vary slightly but within recommended global ranges. These variations could be due to environmental variables, crop management practices, altitude, weather conditions, and soil conditions. The nutritional value equally points to the need to consume more avocados to meet body requirements of some nutrients. Kenyan Hass avocados meet the required export quality in terms of size (calibre), pulp-to-seed and peel ratio was within acceptable limits, the nutritional composition of avocados and their lipid content is in line with those reported in key avocado-producing and exporting countries. The fatty acid profile of the avocados is consistent with high quality lipids with high unsaturated fatty acid content. Continued emphasis on quality improvement, sustainability, and market access will help Kenya strengthen its position in the global avocado trade.

The avocado from Kenya meets the minimum 58% oil; hence, it is suitable for extraction of avocado oil. The fatty acid profile makes Kenyan avocados nutritionally suitable regarding unsaturated fatty acid content. The overall quality of Kenyan avocados conforms to and is similar to that of top global origin destinations like Mexico.

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Conflict of interest

The authors declare no interest whatsoever in the funding and how the research was done.

Author Contribution

FOO: Designed, Coordinated the research, drafted and reviewed the manuscript
BO: writing and reviewing the manuscript
WM: writing and reviewing the manuscript
JKL: writing and reviewing the manuscript
GO: writing and reviewing the manuscript
JA: writing and reviewing the manuscript
WN: writing and reviewing the manuscript
CWM: writing and reviewing the manuscript

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ID: 655

Extraction of Essential Oil from Sour Orange (*Citrus aurantium*) Peels and Evaluation of its Physico Chemical Characteristics

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Abstract

The present work was carried out to obtain essential oil from the sour orange peel (*Citrus aurantium*) which is rich in essential oil through steam distillation. Extraction using distilled water was the control treatment and other treatments were carried out by using 3%, 5%, and 7% $NaHCO_3$. This study determined the yield% of essential oil in four different treatments in freshly extracted essential oil. The Physico-chemical properties of essential oil were determined in freshly extracted essential oil .In performance, T3 (5% $NaHCO_3$) was the best yield% (w/w) with a value of 3.15%. According to this study, using $NaHCO_3$ for essential oil extraction from sour orange peel resulted in a higher essential oil yield than distilled water. The extracted essential oil in sour orange peel has distinct pale yellowish color with a fresh and tangy smell. T3 exhibited that distinct color and odor. Based on the yield% and Physico-chemical analysis, the essential oil extraction using 5% $NaHCO_3$ was the best treatments followed by treatment 4 (7% $NaHCO_3$), treatment 2 (3% $NaHCO_3$) and treatment 1.

Key Words: *Sour orange peel, Extraction, $NaHCO_3$, Essential oil*

ID: 656

Farmer's Attitude Towards Rental Combine Harvester in Thakugaon District

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Abstract

The main purpose of the study was to determine the attitude of the farmers towards combined harvester. The study was carried out at Thakurgaon Sadar upazila of Thakurgaon district under Rangpur division. Ninety-eight (98) farmers were selected as sample from an updated list of 300 farmers' who are rental user of combined harvester by following proper statistical techniques. Data were collected by a pre-tested interview schedule during 10 November to 10 December 2023. Simple and direct questions with different scales were used to obtain information. Pearson Co-efficient of Correlation (r) was computed to explore the relationships between the nine selected characteristics of the farmers and their attitude towards combined harvester. Just more than three-fourths (45.9 percent) of the respondents had moderately favourable attitude while (43.9 percent) of them had highly favourable attitude and only (10.0 percent) of them had lower favourable attitude towards combine harvester. Out of nine selected characteristics, four characteristics of the respondents such as education, farm size, social network and extension media contact had significant positive relationship with their attitude towards combine harvester, but age of the farmers had negative significant relationship with their attitude towards combine harvester. The remaining selected characteristics *e.g.* family size, annual income, level of mechanization experience and exposure to combine harvester technology did not show any significant relationship with their attitude towards combine harvester. Fragmented land & small farm size emerged as the most important constraints expressed by the farmers. The foremost suggestion cited by the farmers was organizing training program by government for the farmers on combine harvester. Increase of direct government and private investment was suggested by the farmers as the last suggestion.

Key words: *Attitude, Rental combined harvester and Farmers'*

ID: 657

Küresel Perspektiften Türkiye'ye: Tarım Ekonomisinde Yeşil Yaka Uygulamaları Üzerine Bir Derleme

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Özet

Küresel iklim değişikliği, doğal kaynakların tükenmesi ve çevresel bozulma gibi tehditler, tarım sektörünün sürdürülebilirlik ekseninde yeniden yapılandırılmasını zorunlu kılmıştır. Bu bağlamda ortaya çıkan "yeşil yaka" kavramı, çevresel etkileri minimize eden, doğa dostu üretim ve hizmetlerde çalışan bireyleri tanımlar. Tarım ekonomisi özelinde yeşil yakalı çalışanlar; organik tarım, su ve toprak kaynaklarının verimli yönetimi, yenilenebilir enerji kullanımı ve çevre koruma gibi alanlarda etkin roller üstlenmektedir.

Bu derleme çalışması, Türkiye ve dünyada tarım sektöründe yeşil yaka istihdamının mevcut durumu, gelişim süreci ve potansiyel etkilerini değerlendirmektedir. Uluslararası örneklerde yeşil ekonomi politikalarının tarımsal istihdamı artırdığı, kırsal kalkınmayı desteklediği ve çevresel sürdürülebilirliği güçlendirdiği görülmektedir. Türkiye'de ise yeşil ekonomi ile uyumlu politikaların yeni yeni şekillenmeye başladığı, ancak bu alanda stratejik planlamaya ve eğitim-eğitim destekli istihdam politikalarına ihtiyaç duyulduğu anlaşılmaktadır.

Çalışma sonucunda, yeşil yaka istihdamının artırılmasının hem çevresel hedeflerin gerçekleştirilmesi hem de ekonomik büyümenin sürdürülebilir temeller üzerine inşa edilmesi açısından kritik öneme sahip olduğu vurgulanmaktadır.

Anahtar Kelimeler: *Yeşil yaka, Sürdürülebilir tarım, İklim değişikliği, Tarım Ekonomisi, Türkiye*

ID: 658

Küresel Perspektiften Türkiye'ye: Tarım Ekonomisinde Yeşil Yaka Uygulamaları Üzerine Bir Derleme

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Özet

Küresel iklim değişikliği, doğal kaynakların tükenmesi ve çevresel bozulma gibi tehditler, tarım sektörünün sürdürülebilirlik ekseninde yeniden yapılandırılmasını zorunlu kılmıştır. Bu bağlamda ortaya çıkan "yeşil yaka" kavramı, çevresel etkileri minimize eden, doğa dostu üretim ve hizmetlerde çalışan bireyleri tanımlar. Tarım ekonomisi özelinde yeşil yakalı çalışanlar; organik tarım, su ve toprak kaynaklarının verimli yönetimi, yenilenebilir enerji kullanımı ve çevre koruma gibi alanlarda etkin roller üstlenmektedir.

Bu derleme çalışması, Türkiye ve dünyada tarım sektöründe yeşil yaka istihdamının mevcut durumu, gelişim süreci ve potansiyel etkilerini değerlendirmektedir. Uluslararası örneklerde yeşil ekonomi politikalarının tarımsal istihdamı artırdığı, kırsal kalkınmayı desteklediği ve çevresel sürdürülebilirliği güçlendirdiği görülmektedir. Türkiye'de ise yeşil ekonomi ile uyumlu politikaların yeni yeni şekillenmeye başladığı, ancak bu alanda stratejik planlamaya ve eğitim-eğitim destekli istihdam politikalarına ihtiyaç duyulduğu anlaşılmaktadır.

Çalışma sonucunda, yeşil yaka istihdamının artırılmasının hem çevresel hedeflerin gerçekleştirilmesi hem de ekonomik büyümenin sürdürülebilir temeller üzerine inşa edilmesi açısından kritik öneme sahip olduğu vurgulanmaktadır.

Anahtar Kelimeler: *Yeşil yaka, Sürdürülebilir tarım, İklim değişikliği, Tarım Ekonomisi, Türkiye*

ID: 660

Impact of Biochemical and Physicochemical Properties on the Organoleptic Attributes of Tea from Different Regions of Bangladesh

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Abstract

Tea is the most consumed beverage in Bangladesh, and it has a great impact on the economy due to its export potential. The organoleptic quality of tea depends on different biochemical compounds and can be affected by physical factors. The objectives of the study were to assess the biochemical and physicochemical properties of black and green tea sourced from six major tea-growing regions of Bangladesh, their relationship with organoleptic properties, and how they are affected. Fifteen Black and green tea samples were collected from different tea-growing regions of Bangladesh. They were analyzed for moisture content, ash content, electrical conductivity, caffeine content, total polyphenol and total flavonoid contents in water and methanol extract, theaflavin, thearubigin, total colour, total brightness, and heavy metal contents. The moisture content of the samples ranged from 4.26% to 7.23%, caffeine content ranged from 2.15% to 3.81%, and Thearubigin-Theaflavin ratio ranged from 5.14 to 6.69. The total polyphenol content of black tea was found to be higher in water extract than in methanol extract, whereas total flavonoid content was found to be higher in methanol extract. In green tea samples, total polyphenol content, total flavonoid content, and caffeine content are found to be positively correlated with organoleptic properties, with a total correlation coefficient of 0.95, 0.97, and 0.96, respectively. In black tea samples, organoleptic properties are positively correlated with the Thearubigin-theaflavin ratio (0.76), caffeine content (0.74), and weakly correlated with total polyphenol (0.22) content and total flavonoid content (0.34). Moisture content is strongly negatively correlated with organoleptic attributes in both green tea (-1.0) and black tea (-0.91). These findings highlight the critical role of biochemical profiling, particularly thearubigin–theaflavin ratio, polyphenol content, in determining the organoleptic properties of Bangladeshi teas. Moisture content has a deteriorating effect on the sensory properties of tea, and it should be maintained properly during the processing and storage of tea.

Keywords: *Tea, Organoleptic Properties, Total Polyphenol Contents, Total Flavonoid Contents, Theaflavin, Thearubigin*

ID: 661

Evaluation of Early Rice Genotypes for Yield and Yield Attributing Characters in Madhesh Province of Nepal

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Abstract

Rice plays crucial role in sustaining nutrition and sustaining livelihoods nutritional and livelihood globally but lack of high yielding and early maturing varieties cause problem in sustainable production. Thus, the study was conducted to evaluate the performance of early rice genotypes in Madhesh province, focusing on yield and yield attributing characters. The research was laid in randomized complete block design (RCBD) with two replications and twenty-four genotypes (2 check varieties Hardinath-1 & Hardinath-3) in CNRM Bardibas. Geographically, it is suited at altitude 26˚52'0''8North, longitude 85˚49'96'' East; 78 m above sea level, AFU. The planting distance between the rice plant was 20*20 cm with plant plot size:1.5x3=4.5 and the spacing between two plots consecutive plots was maintained 0.5 m. Key agronomic traits of growth, yield and yield attributes characters were recorded. Data was entered and tabulated using MS-Excel and analyzed using Gen-stat ver. 2015. Mean separation was done by DMRT at 5% level of significance. The results revealed that highest yield (6.87 t/ha) was achieved by the genotypes IR-18-A-2294, followed by IR-19-A-5000 (6.516 t/ha), NS-314(6.24 t/h), NS-278(6.26 t/h), Hardinath-3(6.24t/h) and least by NS-232(3.91t/h). Hardinath-1 (86.5 DAT) had early maturity followed by NS-201 (91 DAT), Hardinath-3 (94 DAT), IR-132T799(96DAT) & IR-132084-B-1191-1-2-B-12 (96 DAT) whereas late maturity was observed in NS-313 (104 DAT) and yields were 5.24 t/h, 5.14 t/h, 6.24 m/t, 5.37 t/h, 4.87 t/h & 5.98t/h respectively. Based on grain quality and yield, IR-19-A-5000, IR-18-A-2294 were found as high yielding genotypes respectively, while based on earliness and yield potential Hardinath-1, IR-132T799 and Hardinath-3 were found superior among tested. These results provide valuable insights into the selection and development of rice varieties adapted to the specific agro-ecological conditions of Nepal.

Keywords: *Earliness, Rice, Genotypes, Yield, Yield Attributes.*

Introduction

Rice (*Oryza sativa* L.,2n=2x=24) is essential to nutrition, livelihoods, and cultural activities, supporting more than half of the world's population and contributing significantly to global food security(Fukagawa & Ziska, 2019). Rice is a major staple food crop and ranks first in position in terms of production and productivity in Nepal(AITC, 2024; MoALD, 2024). Rice supplies nearly 20% of the economic to its agricultural GDP, and 7% of its overall GDP comes from rice, making it a vital crop in Nepal(Devkota et al., 2018). It is cultivated in an area of 1447789 hectares, yielding an average of 3.7 t/ha. where Mahottari District shares 3.00 % production of national production, located in Terai,is one of the productive locations for high rice production due to its suitable agro-climatic condition(AITC, 2024; MoALD, 2024).

Inconsistent yield due to poor soil, water scarcity, and pest susceptibility, raises concerns about its stability. A weak seed production and distribution system in Nepal limits farmers' access to quality rice seeds(Prasad et al., 2017). Insufficient research on early rice compatibility with farmer needs. This has made it necessary to concentrate on increasing productivity through agronomic development and genetic enhancement. Developing high-yielding, early-maturing rice varieties is necessary to address Nepal's food security concerns, particularly in the Terai region, which serves as the country's agricultural hub(Dhungana et al., 2022). The prevention of terminal drought and the ability to plant successive crops on schedule are two major advantages of early-maturing genotypes for cropping intensity optimization. Sustainable production is hampered by the lack of cultivars appropriate for Nepal's agroecological conditions(B. B. Adhikari et al., 2018). Grain yield is a complicated trait impacted by genotype-environment interactions, and finding improved genotypes for it requires a thorough assessment of yield-related traits(Liang et al., 2015).

The environment has a significant impact on rice grain production, which is a quantitative polygenic characteristic. When selecting germplasm based on the genetic variation available, it is important to consider the extent and significance of the relationship between yield and its components(B. N. Adhikari et al., 2018; Aditya & Bhartiya, 2013). The success of breeding programs depends on the population's level of genetic variability as well as the heritability of the targeted features. With new plant type attributes linked to crop productivity, several morphological features are crucial for increased rice production. The phonological traits of rice that are also linked to the yield potential of the many rice varieties in order to choose the best variations for further rice breeding(Aditya & Bhartiya, 2013). Thousand rice varieties that are well suited to the regional conditions have been developed through selection from the cultivated material many years ago. Under biotic and abiotic stress

conditions, several of those rice varieties have higher yield potential and superior quality traits(Amirova et al., 2024).Keeping in view in the above fact, present evaluation was done with objectives to determine appropriate high-yielding rice genotypes and earliness under the conditions of the Terai region and assess several rice genotypes for yield and yield characteristics.

Materials And Methods

Experimental site

The study was conducted during the 2024 monsoon season (June-October) at College of Natural Resources Management Bardibas (CNRMB) experimental farm in Bardibas, Mahottari District, Nepal, which is suited in the inner terai of Nepal. Geographically, it is suited at altitude 26˚52'0''8North, longitude 85˚49'96'' East; 78 m above sea level. The region receives an average annual rainfall 1200-1400 mm. The soil texture was found silty clay loam (alluvial deposits), pH was slightly acidic (5.6- 6.2) and nutrient status was low organic carbon (0.8-1.2%), moderate nitrogen (0.10-0.15%), deficient available phosphorus (<20 kg ha^{-1}), and high potassium content.

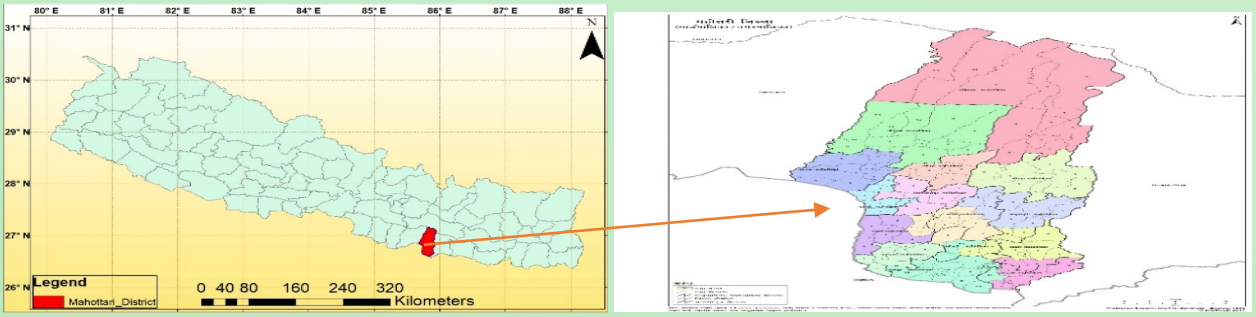


Figure 1: A map showing experimental site

Experimental design and crop management

The research was laid out in one factorial randomized complete block design (RCBD) with two replications and twenty-four genotypes (2 check varieties Hardinath-1 & Hardinath-3) in CNRM Bardibas, AFU. The planting distance between the rice plant was 20*20 cm with plant plot size:1.5x3=4.5 and the spacing between two plots consecutive plots was maintained 0.5 m. The experimental plots and dry seed bed were leveled and prepared using traditional practices. A raised nursery bed was conducted using the dry method of preparing nursery beds. The nursery seedlings of 21 days old were transplanted in June 2024.

The plot size was 4.5 m^2. The fertilizer were applied using urea diammonium phosphate (DAP),and muriate of potash (MOP) at rate of 120:40:40 N:P_2O_5: K_2O [nitrogen (N), phosphorus (P2O5), and potassium 67 68 (K2O)] ha-1(AITC, 2024). The full doses of P2O5 and K2O, along with half of the dose of N, were applied as the basal dose, and the remaining 50% of the nitrogenous fertilizer was applied into two split doses. The first one was used during tillering, and the second one was used after panicle initiation. Every other intercultural operation and mandatory practice package was completed as needed and in compliance with the recommended practices.

Plant materials

The rice genotypes were obtained from National Rice Research Program, Hardinath, Dhanusha, Nepal. The list of rice genotypes used in this experiment is given in **Table 1**.

Data Collection and statistical analysis

Panicle initiation 80%, days to maturity, plant height, test weight, filled grain per panicle, sterility percentage, biomass yield, harvest index, effective tillers were recorded. The grain yield at 12% moisture was calculated using the formula adopted (Shrestha et al., 2021). Data was entered and tabulated using MS-Excel and analyzed using Gen-stat ver. 2015. Key agronomic traits of growth, yield and yield attributes characters were processed to Analysis of Variance (ANOVA). The significant of the differences among the treatments of the rice varieties was estimated with the help of Duncan's Multiple Range Test (DMRT)at a 5% level of probability.

Results And Dıscussıon

Phenological characteristics

Panicle initiation 80%

the panicle emergence was highly varied with the genotypes at 1% level of significance (Table2).The result depicts that IR-132084-B-1191-1-3-B-5, IR-19-A-3197,NS-224 and NS-313 were found delayed in panicle initiation while in 71 (DAT). Hardinath-1 and NS-201showed earlines in panicle emergence. The days to panicle initiation may be influenced by factors such as water and soil conditions, planting and sowing techniques, and its early maturing genetic ability and translation time(Ashfaq, 2012; Hussain et al., 2005).

Table 1. List of24 rice genotypes used in the experiment at CNRM Bardibas, Nepal in 2024

Treatments	Genotypes	source
T1	IR-127153-2-3-5-1-B-B	IRRI
T2	Hardinath-3	NRRP
T3	IR-12C170	IRRI
T4	IR-97205-73-1-2-2	IRRI
T5	IR-116713-B-B-34-3-B-B	IRRI
T6	NS-232	IRRI
T7	NS-314	IRRI
T8	IR-18-A-2294	IRRI
T9	NS-278	IRRI
T10	NS-224	IRRI
T11	IR-19-A-4494	IRRI
T12	IR-19-A-5000	IRRI
T13	NS-188	IRRI
T14	NS-313	IRRI
T15	Hardinath-1	NRRP
T16	NS-201	IRRI
T17	IR-19-A-3197	IRRI
T18	IR-132084-B-1191-1-3-B-5	IRRI
T19	IR-132084-B-628-1-1-B-9	IRRI
T20	IR-13C121	IRRI
T21	IR-132084-B-1191-1-2-B-12	IRRI
T22	IR-132T799	IRRI
T23	IR-127152-1-6-7-1-B-B	IRRI
T24	NR-2312-59-1-3-1-1	NRRP

Table 2. Phenological Characters affected by of 24 rice genotypes in CNRM Bardibas, Mahottari, Nepal in 2024.

Genotypes	Panicle Initiation 80% (DAT)	Days to Maturity (DAT)	Plant Height (cm)
IR-127153-2-3-5-1-B-B	64^{de}	98^{efg}	121^{cde}
Hardinath-3	62.50^{ef}	94h	135.6^{abc}
IR-12C170	68^{bc}	97.5^{fg}	115.7^{de}
IR-97205-73-1-2-2	64^{de}	97.5^{fg}	118.9^{cde}
IR-116713-B-B-34-3-B-B	64^{de}	99^{cdef}	124^{bcde}
NS-232	63^{ef}	96^{gh}	128.5^{bcd}
NS-314	63^{ef}	97.5^{fg}	126.2^{bcde}
IR-18-A-2294	68.5^{abc}	99^{cdef}	147.7^{a}
NS-278	68.5^{abc}	99^{cdef}	124.7^{bcde}
NS-224	70.5ab	98.5^{def}	130.1^{bcd}
IR-19-A-4494	63^{ef}	96^{gh}	112.3^{de}
IR-19-A-5000	61^{f}	96^{gh}	108.1^{ef}
NS-188	68.5^{abc}	102^{b}	113.1^{de}
NS-313	70.5^{ab}	104^{a}	141.6^{ab}
Hardinath-1	55^{h}	86.5^{k}	113.2^{de}
NS-201	58^{g}	91^{j}	134.2abc
IR-19-A-3197	71^{a}	100^{bcde}	123.8^{cde}
IR-132084-B-1191-1-3-B-5	71^{a}	101^{bc}	113.9^{de}
IR-132084-B-628-1-1-B-9	66.5^{cd}	100^{bcde}	127.1^{bcd}
IR-13C121	68.5^{abc}	100.5^{bcd}	94.5^{f}
IR-132084-B-1191-1-2-B-12	68.5^{abc}	96^{gh}	108.7^{ef}
IR-132T799	68.5^{abc}	96^{ghi}	123.7^{cde}
IR-127152-1-6-7-1-B-B	67^{c}	99^{cdef}	114.4^{de}
NR-2312-59-1-3-1-1	66.5^{cd}	99^{cdef}	118.6^{cde}
F-test	<0.001(***)	<0.001(***)	<0.001(***)
CV%	1.8	0.9	6.1
LSD (0.05)	2.508	1.913	15.44
Grand Mean	65.94	97.62	121.5

LSD= Least significant Difference, CV= Coefficient of Variation, * = significant at (P<0.05), ** = significant at (P<0.01), *** = significant at (P<0.001), NS= Non-Significant. DAT- Days after transplanting.

Genotype genetic diversity may be one of the cause of the variation in panicle initiation(Khalil et al., 2009).Similarly, genetic composition of the foreign lines and genotypic environmental interaction may be the cause of the variation in days to panicle initiation(Marwat, 2002).

Days to maturity

The days to maturity of the examined rice genotypes varied significantly at 1% level of significance (Table 2). The results indicated that NS-313had the highest number of days to maturity 104 (DAT), followed by NS-188in 102 (DAT). The Hardinath-1 genotype was showed earlier in maturity (86 DAT),followed byNS-201(91 DAT).Variation in marturity depend upon the panicle emergence and availability of resource at that time. Maturity of different genotypes may varied due to genetic and environment interaction(Karim et al., 2007).

Plant Height (cm)

The plant height was significantly influenced by genotypic variation at 1% level of significance. (Table 2). IR-18-A-2294 had highest plant height of 147.7 cm followed by NS-313 (141.6cm). The shortest plant height was observed in IR-13C121 (94 cm). followed by IR-19-A-5000 (108.1cm).It has been determined that the climatic requirements of each genotype of rice are distinct, which may account for the variance in plant height among these genotypes(Rabbani et al., 2010).

Yield and Yield Attributing Characteristics:

1000 grain weight (gram)

Difference in 1000 grain weight was significant to various genotypes (Table 3).Thousand grain weight of tested ranged from (20.75-29.24).IR-18-A-2294 shown the highest grain weight of 29.24gm, followed by IR-127153-2-3-5-1-B-B (28.57 gm). And lowest was shown in NR-2312-59-1-3-1-1 (20.75 gm) followed by Hardinath-1 (21.24 gm).Several traits showed highly significant variance, and these attributes were controlled by genotypic differences across the tested genotypes(Tahir et al., 2002).

Panicle Length (cm)

The panicle length was observed significant difference in the panicle length among the observed genotypes(Table 3). Longest panicle length was observed on NS-313 (30.19 cm), followed by IR-18-A-2294 (30.01 cm) and shortest panicle length was observed on NR-2312-59-1-3-1-1 (19.85 cm), followed by R-19-A-5000 (23.12 cm). Different rice genotypes may differ in their genetic composition, which could account for the variance in panicle length(Sultana et al., 2014). The genetic variability for several traits in ten rice genotypes, and he found that these traits were controlled by genetics and could be used to choose a desired characteristic of rice(Cha-um et al., n.d.; Tahir et al., 2002).

Filled Grain per Panicle

The number of filled grain per panicle of different genotypes of rice was shown significantly difference under this experiment (Table 3). The highest number was observed in NS-201 (135.8), followed by IR-18-A-2294 (131.6). And lowest number was observed by NS-224 (68.9), followed by IR-12C170 (74.9). The variance was shown due to panicle length, days to maturity and traits among genotypes(Karim et al., 2014). The length of the panicles and the configuration of their spikelets determine the amount of grain per panicle(Balasubramanian et al., 2006; Zhao et al., 2020).

Sterility percentage

Analysis of various genotypes indicates that the differences in sterility percentages amongst the genotypes are statically significant, as presented in Table 3. The genotypes IR-12C170 exhibited the highest sterility percentages at 43.60%, followed by IR-127153-2-3-5-1-B-B at 41.27%. Conversely, the lowest sterility percentage was observed in NS-313 at 13.9%, followed by NS-201 at14.20%. The component of variation for Sterility percentage was due to A lack of boron, which is essential for the growth of pollen tubes, varies by genotype, and drought stress interferes with the uptake of nutrients and water, which impacts spikelet development.(Ali et al., 2013).

Biomass Yield (ton ha^{-1})

The biomass production of the several rice genotype was non-significant (Table 4). The maximum biomass production 32.44 t/ha, was obtained by the genotype NR-2312-59-1-3-1-1, followed by IR-18-A-2294 which yielded 30.01 t/ha. Conversely, And lowest production 21.28 t/ha, was obtained by the genotype IR-132084-B-1191-1-2-B-12, followed by Hardinath-1 which yield 21.82 28 t/ha).These differences suggest that both genetic factors and breeding history contribute to biomass yield variations among rice genotypes(Chen et al., 2008; Jahn et al., 2011).

Harvesting Index

The research revealed that the harvesting index of different genotypes of rice significant difference relation among them (Table 4). The mean harvesting index of different rice genotypes was highest in IR-19-A-5000 (28.40), followed by IR-19-A-4494 (25.11). And lowest was IR-12C170 (13.5), followed by NS-232 (15.14). The variation in harvesting index could be attributed to genetic background plays a significant role in determining harvesting index.(Cui et al., 2000)

Table 3. Yield and Yield Attributing Characters affected by 24 rice genotypes in CNRM Bardibas, Mahottari, Nepal in 2024.

Genotypes	Test Weight (gm)	Panicle Length(cm)	Filled Grain/Panicle	Sterility Percentage
IR-127153-2-3-5-1-B-B	28.57^{ab}	25.55^{abcde}	82.2^{def}	41.27^{ab}
Hardinath-3	22.04^{fghij}	25.90^{abcde}	129.9^{abc}	26.02^{bcdefg}
IR-12C170	27.03^{abc}	27.68^{abcde}	74.9^{ef}	43.60^{a}
IR-97205-73-1-2-2	26.10^{abcd}	28.23^{abcde}	98.5^{bcdef}	38.67^{abcd}
IR-116713-B-B-34-3-B-B	23.69^{defghij}	29.25^{abc}	123.1^{abc}	26.89^{bcdefg}
NS-232	26.86^{abcd}	25.70^{abcde}	103.1^{abcde}	27.22^{bcdefg}
NS-314	25.44^{bcde}	28.24^{abcde}	102.2^{abcdef}	33.11^{abcde}
IR-18-A-2294	29.24^{a}	30.01^{ab}	131.6^{ab}	19.95^{efg}
NS-278	25.13^{cdef}	26.25^{abcde}	102.5^{abcde}	35.07^{abcde}
NS-224	26.69^{abcd}	23.34^{def}	68.9^{f}	31.02^{abcde}
IR-19-A-4494	22.53^{efghij}	25.33^{abcde}	134^{a}	24.32^{defg}
IR-19-A-5000	21.84^{ghij}	23.12^{ef}	114^{abcd}	14.66^{fg}
NS-188	24.70^{cdefgh}	25.96^{abcde}	78.2^{ef}	41.11^{abc}
NS-313	27.16^{abc}	30.19^{a}	122.6^{abc}	13.9^{g}
Hardinath-1	21.24^{ij}	25.53^{abcde}	128.1^{abc}	25^{bcdefg}
NS-201	24.38^{cdefghi}	25.33^{abcde}	135.8^{a}	14.20^{g}
IR-19-A-3197	24.90^{cdefg}	28.61^{abcd}	108.3^{abcde}	19.68^{efg}
IR-132084-B-1191-1-3-B-5	26.39^{abcd}	26.66^{abcde}	103.5^{abcde}	22.38^{defg}
IR-132084-B-628-1-1-B-9	21.66^{hij}	24.19^{cdef}	99.4^{bcdef}	31.57^{abcde}
IR-13C121	25.65^{bcde}	25.49^{abcde}	82^{def}	30.67^{abcdef}
IR-132084-B-1191-1-2-B-12	27.35^{abc}	24.93^{abcdef}	76.1^{ef}	28.74^{abcdefg}
IR-132T799	21.29^{ij}	24.69^{bcdef}	131.3^{ab}	24.76^{cdefg}
IR-127152-1-6-7-1-B-B	24.86^{cdefg}	25.24^{abcde}	97^{cdef}	28.73^{abcdefg}
NR-2312-59-1-3-1-1	20.75^{j}	19.85^{f}	119.4^{abc}	33.23^{abcde}
F-test	<0.001(***)	0.031(*)	<0.001(***)	0.004(**)
CV%	5.4	8.5	13.1	23.8
LSD (0.05)	2.766	4.594	28.82	13.868
Grand Mean	24.81	26.05	106.1	28.16

LSD= Least significant Difference, CV= Coefficient of Variation, * = significant at (P<0.05), ** = significant at (P<0.01), *** = significant at (P<0.001), NS= Non-Significant.

Table 4. Yield and Yield Attributing Characters affected by 24 rice genotypes in CNRM Bardibas, Mahottari, Nepal in 2024.

Genotypes	Biomass Yield (ton ha^{-1})	Harvesting Index	Grain Yield (ton ha^{-1})
IR-127153-2-3-5-1-B-B	27.48^{abcd}	19.01^{defghi}	5.21^{bcdef}
Hardinath-3	28.37^{abcd}	22.11^{bcdef}	6.24^{abc}
IR-12C170	29.48^{abc}	13.50^{j}	3.983^{ef}
IR-97205-73-1-2-2	26.34^{abcd}	18.43^{efghi}	4.83^{cdef}
IR-116713-B-B-34-3-B-B	24.62^{bcd}	21.96^{bcdef}	5.40^{abcdef}
NS-232	26.12^{bcd}	15.14^{ij}	3.91^{f}
NS-314	28.51^{abcd}	22.26^{bcde}	6.34^{abc}
IR-18-A-2294	30.01^{ab}	23.10^{bcd}	6.87^{a}
NS-278	28.30^{abcd}	22.15^{bcdef}	6.26^{abc}
NS-224	28.97^{abcd}	16.98^{hij}	4.29^{cdef}
IR-19-A-4494	24.21^{bcd}	25.11^{ab}	6.07^{abcd}
IR-19-A-5000	22.94^{bcd}	28.40^{a}	6.51^{ab}
NS-188	25.72^{abcd}	21.14^{bcdefg}	5.47^{abcde}
NS-313	24.91^{abcd}	24.04^{b}	5.98^{abcd}
Hardinath-1	21.82^{cd}	24.04^{b}	5.24^{bcdef}
NS-201	24.83^{abcd}	21^{bcdefgh}	5.14^{bcdef}
IR-19-A-3197	25.41^{abcd}	19.25^{cdefgh}	4.89^{cdef}
IR-132084-B-1191-1-3-B-5	25.13^{abcd}	18^{fghi}	4.58^{def}
IR-132084-B-628-1-1-B-9	25.84^{abcd}	17.23^{ghij}	4.45^{ef}
IR-13C121	22.63^{bcd}	19.43^{cdefgh}	4.41^{ef}
IR-132084-B-1191-1-2-B-12	21.28^{d}	22.72^{bcd}	4.87^{cdef}
IR-132T799	23.06^{bcd}	23.21^{bc}	5.37^{bcdef}
IR-127152-1-6-7-1-B-B	22.27^{cd}	21.04^{bcdefgh}	4.66^{def}
NR-2312-59-1-3-1-1	32.44^{a}	16.92^{hij}	5.48^{abcde}
F-test	0.111 (NS)	<0.001(***)	0.003(**)
CV%	12.1	8.4	11.8
LSD (0.05)	6.484	3.573	1.2888
Grand Mean	25.86	20.67	5.3

LSD= Least significant Difference, CV= Coefficient of Variation, * = significant at (P<0.05), ** = significant at (P<0.01), *** = significant at (P<0.001), NS= Non-Significant.

PHOTOS



(A) (B)

(C)

Figure 2: A Panicle initiation stage of rice B. Maturity stage of rice C. Layout of rice experiment conducted in CNRM Bardibas

Grain Yield (ton ha^{-1})

When evaluating the grain yield of the tested rice genotypes against the standard (2 check varieties (Hardinath-1 & Hardinath-3), the majority of them were found to be better and significant (Table 4). The results revealed that highest yield (6.87 t/ha) was achieved by the genotypes IR-18-A-2294, followed by IR-19-A-5000 (6.516 t/ha), NS-314(6.24 t/h), NS-278(6.26 t/h), Hardinath-3(6.24t/h) respectively and least by NS-232 (3.91 t/h), followed by IR-12C170 (3.983 t/h).As breeding materials for confirmation, these superior rice genotypes over the standard check in terms of grain yield might be examined further.(AITC, 2024; Pervaiz et al., n.d.)

Conclusion

A rice breeding program's main objective is to evaluate the genotypes of rice for a particular region or niche. The finding of this study showed that based on grain quality and yield, IR-19-A-5000, IR-18-A-2294 were found as high yielding genotypes respectively, while based on earliness and yielding potential Hardinath-1, IR-132T799 and Hardinath-3 were found superior among tested.

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Conflict Of Interest

Authors declare no conflict of interest exists.

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Bread Waste Patterns in Algeria: Insights into Sociodemographic Influences and Management Practices

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Abstract

Bread waste is a critical issue in North Africa, exacerbated by bread subsidies and cultural consumption patterns. This study explores household bread storage, wastage, and management practices in Algeria, analyzing their associations with sociodemographic variables.

An online survey was performed on 316 respondents (62.8% female, 70% aged from 25 to 60 years old) from September, 2023 to December, 2023. The questionnaire asked questions to determine bread storage and management practices and bread wastage levels, as well as socio-demographic characteristics of respondents. Data analysis was based on percentages and Chi-square tests, using SPSS v25 software.

Findings of Algerian households revealed that bread is primarily stored in freezers (83.8%) and at room temperature (76.5%), with plastic bags being the most common storage medium (47.5%). Bread is typically stored for two days (46.1%), with storage duration significantly associated with age and marital status ($p < 0.05$). Notably, 55.8% of respondents reported discarding stored bread, with this behavior significantly linked to gender, age, and marital status ($p < 0.05$).

Bread management strategies in Algeria include reuse in meals (87.0%), reheating (82.5%), and feeding to animals (83.1%). These practices were significantly influenced by gender, household size, and education level ($p < 0.05$). Furthermore, ethical and religious considerations were the primary motivations for reducing bread waste, cited by 47.9% and 36.6% of respondents, respectively. However, environmental and economic concerns were less prominent motivations, indicating a gap in awareness of the broader implications of bread waste.

Policy recommendations from respondents highlighted the need for educational campaigns (38.8%), quality improvements for enhanced preservation (31.1%), and adjustments to bread subsidies (21.4%) to better reflect production costs. These findings emphasize the importance of culturally tailored interventions that address specific demographic behaviors and motivations to effectively mitigate bread waste in Algeria.

Key Words: *bread waste, Algeria, storage practices, sociocultural factors, food sustainability, policy recommendations*

ID: 663

Eating Fresh Strawberry Fruits Free from Pesticide Residues by Using 28-Homobrassinolide.

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Abstract

One of the most important goals is producing healthy food to eliminate the harmful effects of pesticide residues in plant foods such as grains, vegetables and fruits. There is no doubt that applying good farming practices such as relying on biological pest control and plant growth regulators to achieve the goal of eliminating the dangers of pesticides residues to human health. This is proven by our study using GC-MSMS and LC-MSMS through a full scan of samples of fresh Strawberry fruits (Fragaria × anannasa Duch) var 'Sensation' from the private agricultural field were obtained from badr district, el Beheira Governorate, Egypt. All of which were proven by analysis to be free of the pesticide residues. The results showed that 28-Homobrassinolide at 0.05 mg/l in a greatest decrease in concentrations of pesticide residues (imidacloprid, fenpyroximate, difenoconazole, azoxystrobin, fludioxonil and Lambda-cyhalothrin). Overall, 28-Homobrassinolide at 0.05 mg/l improved detoxification of pesticide residues from fresh strawberry fruits.

Key Words: *Pesticide residues, Strawberries, GC-MSMS, LC-MSMS, 28-Homobrassinolide.*

Introduction

Strawberry (Fragaria × ananassa) known as false fruit is grown in temperate, tropical and subtropical regions of the world and is a member of the Rosaceae family (Trejo-Téllez & Gómez-Merino, 2014). Its excellent flavour, taste and nutritional value made (Rajwana et al., 2017). Strawberry (Fragaria × ananassa Duch.) Is a vital and economical fruit crop that can be grown in a wide range of environments. Customers attracted to its appealing to flavour and aroma, its broad acceptance as a preferred fruit (Lewers et al., 2020; Fecka et al., 2021).

Pesticides known as Toxic chemicals are frequently employed to manage diseases, weeds and pests in order to guarantee crop quality and productivity (Collotta et al., 2013). Because of their negative impact on ecosystems, pesticide residues are now more widely acknowledged as pollutants in the environment (Song et al., 2007). Brassinosteroids (BRs) diversified class of steroid phytohormones (polyhydroxysteroids), (BRs) have a wide range of biological roles (Nolan et al., 2020; Qiao et al., 2022). BRs play important roles in development, plant growth, adaptation to environmental stress and fruit quality (Siddiqi & Husen, 2021; Zhang & Yang, 2021; shehata, 2024). In various types of crops, such as cucumber, mustard, tomato (Lycopersicon esculentum), strawberry (Fragaria ananassa), grapes, and tea (Camellia sinensis), exogenous application of the BR analogue 24-epibrassinolide (EBR) decreased pesticide residues (Sharma et al., 2019; Wang et al., 2017; Xia et al., 2006, 2009; Zhou., 2015). The objectives of this study were to use 28-Homobrassinolide as an exogenous spray to enhance detoxification of pesticide residues from fresh strawberry fruits. For growing healthy food free from any pesticide residues to protect humanity from potential illnesses.

Materials and Methods

Chemicals and Reagents

Certified reference material of GC-MSMS Pesticide combinations including 9 multi pesticide residue mixture as listed below.

GC Multiresidue Pesticide Standard - 185 components including,

Allidochlor, Dichlofluanid, Biphenyl, Mevinphos, 3,4-Dichloroaniline, Etridiazole, Pebulate, N-(2,4-Dimethylphenyl)Formamide ,Captafol, Methacrifos, Chloroneb, 2-Phenylphenol, Pentachlorobenzene, Tecnazene, Propachlor, Diphenylamine, 2,3,5,6-Tetrachloroaniline, Cycloate, Chlorpropham, Ethalfluralin, Trifulralin, Benfluralin, Sulfotep, Diallate , Phorate, Alpha -HCH, Diallate isomer, Hexachlorobenzene, Dichloran, Pentachloroanisole, Atrazine, Clomazone, Beta-HCH, Gamma-HCH(lindane), Terbuthylazine, Terbufos, Profluralin, Quintozene, Propyzamide, Disulfoton, Tefluthrin, Delta-HCH, Isazofos, Tri-allate, Chlorothalonil, Endosulfan-alpha, Prapanil, Dimethachlor, Acetochlor isomer, Vinclozolin, Chlorpyrifos-Methyl, Cypermethrin, Tolclofos-Methyl, Alachlor, Acetochlor, Heptachlor, Metalaxyl, Fonofos, Pentachlorobenzonitrile, Pyrimethanil, Diazinon, Etofenprox, Fluchloralin, Fenchlorphos, Prodiamina, Fenitrothion, Pirimiphos-methyl, Malathion, Methyl-Pentachlorophenyl sulfide, Dichlobenil, Metolachlor, Anthraquinone, Fenthion, Aldrin, Chlorpyrifos, Parathion, Triadimefon, 4,4-Dichlorobenzophenone, Chlorthal-dimethyl, Fenson, Diphenamid, Pirimiphos-ethyl, Bromophos-Methyl, Isopropalin, Cyprodinil, Isodrin, Metezachlor, Pendimethalin,

Penconazole, Chlozolinate, Bioallethrin, Fipronil, Heptachlor-exo-epoxide, Tolyfluanid, Chlorbenzilate, Bromfenvinphos-Ethyl, Quinalphosl, Triadimenol, Folpet, Procymidone, Chlorbenside, Bromophos-Ethyl, Cis-Chlordane, 2,4-DDE, Paclobutrazol, Cis-Tetrachlorvinphos, Fenamiphos, Endosulfan-beta, Flutriafol, Trans-Chloridane, Chlorfenvinphose, Flutolanil, Cis-Nonachlor , Iodofenphos, Prothiophos, Fludioxonil, Profenfos, Pretilachlor, Oxadiazon, 4,4-DDE, Oxyfluorfen, Myclobutanil, Dieldrin, Flusilazole, Bupirimate, 2,4-DDD, Fluazifop-P-butyl, Chlorfenapyr, Nitrofen, Chlorobezilate, Endrin, Endosulfan Ether, 4,4-DDD(TDE), Ethion, 2,4-DDT, Chlorthiophos, Trans-Nonachlor, Triazophose, Sulprofos, Enderin Aldehyde, Enderin ketone, Carfentrazone-Ethyl, 4,4-methoxychlor-olefin, Carbophenothion, Norflurazon, Edifenphose, Lenacil, 4,4-DDT, Endosulfan total, Hexazinone, o,p-Methoxychlor-olefin, Methoxychlor(DMTD), Propargite, Piperonyl butoxide, Resmethrin, Pyridaphenthion, Cis-Bifenthrin, Tetramethrin, Bromopropylate, Phosmet, EPN, Fenpropathrin, Tebufenpyrad, Phenothin, Phenothrin, Tetradifon, Pyriproxyfen, Azinophos-Methyl, Leptophos, Iambda-Cyhalothrin, Mirex, Pyrazophos, Fenarimol, Azinophose-Ethyl, Pyraclofos, Cis-Permethrine, Trans-Permethrin, Pyridaben, Coumaphos, Fluquinconazole, Cyfluthrin, Fenvalerate, Flucythrinate, isomerFlucythrinate and Fluridone.

LC Multiresidue Pesticide Standard - 45 components including:

Rotenone, Spirodiclofen, azoxystrobin, Flufenoxuron, Indoxacarb, Chlorfluazuron, Linuron, Carbofuran, Bendiocarb, Mevinphors, Ametryn, Dimethoate, Carboxin, 3-Hydroxycarbofuran, Dicrotophos, Primicarb, Forchlorfenuron, Clothianidin, Thiacloprid, imidacloprid, Dithofencarb, Chloroxuron, Thiamethoxam, Spiroxamine, Propham, Tricyclazole, Cycluron, Carbaryl, Thiabendazole, Promecarb, Propoxur, difenoconazole, Fenoxycarb, Diflubenzuron, Cyazofamid, Benalaxyl, Boscalid, Triflumeron, Propargite, Spiromesifen, Spirotetramat, fenpyroximate, Dimethomoroph, Spinosad, Spinetoram, and Emamectin benzoate were purchased from CAP- CHEM (Augsburg, Germany), with certified purity ranging from 97% to 99.9%. Acetonitrile, ammonia solution, sodium chloride, acetic acid, triphenylphosphate (TPP), and ethoprophos were obtained from chem- lab (Belgium), and QuEChERS extraction mix kit from CHROMABOND (Valencienner St. 11, 52355 Duren, Germany). All the organic solvents used were higher performance liquid chromatography (HPLC) grade.

Field experiment

The present study was carried out during in two successive 2023 and 2024 on strawberry (Fragaria X ananassa Duch) var "Sensation", grown under a drip irrigation system in a private field at badr district, el Beheira Governorate, Egypt. Soil texture was sandy and drip irrigation system was adopted. Strawberry plants had been under the standard agriculture practices throughout the seasons. Three replications were used for each treatment. The treatments included: control (tap water spray), 28-Homobrassinolide at (0.025 mg/l) and 28-Homobrassinolide at (0.05 mg/l). The non-ionic surfactant Top film at 0.05% (V/V) was added to all treatments to reduce the surface tension and to increase the contact angle of sprayed droplets. These treatments were arranged in Analysis of Variance (ANOVA) for Randomized Complete Block Design (RCBD).

Samples collection

Fresh strawberry fruits were picked at mid-December after 5 days of pre-harvest treatments, when bright red color (3/4 of surface showing red) at the same ripening stage. The fruits were selected based on the uniform color, same size and no pests, as well as the absence of blemishes or disease, with no physical damage. The samples included 1kg from fresh strawberry fruits for each replicate for pesticide residue analysis. The samples were collected from private field at badr district, el Beheira Governorate, Egypt. The sampling was performed in accordance with the general principles and methods of the European Commission (EC) directive 2002/63/EC for establishing MRLs in food commodities (EC, 2002). All the samples were placed in sterile polythene bags, in an ice box, to avoid contamination and deterioration, labeled, and transported to the laboratory for processing. The homogenized samples were analyzed immediately.

Sample Extraction and Clean-Up

The extraction and clean-up method used was based on QuEChERS (quick easy cheap effective rugged and safe) sample preparation method for pesticides (BS EN 15662:2018). An aliquot of 10 g of homogenized sample was placed in a 50 mL centrifuge, and 10 mL of acetonitrile was added. The mixture was vortexed for one minute, followed by adding 4 g of magnesium sulphate anhydrous, 1g trisodium citrate di hydrate, 0.5 g disodium hydrogen citrate and 1 g of sodium chloride. The clean-up was carried out by transferring 3 ml of supernatant into another tube containing 75 mg of primary and secondary amine (PSA), 75 mg of C18 Sorbent (for wheat) and 450 mg of magnesium sulphate. After agitation and centrifugation, the aliquots of the extract were reconstituted to 1.5 mL vial for gas chromatography (GC-MS/MS) (Mustapha et al., 2017).

Solutions and Standards

From Reference Standard pesticide mixtures (9 Mixture 100ppm each compound for GC-MS/MS and 10 mixtures 100ppm each compound for LC-MSMS), stock solutions (1 ppm) were prepared in acetonitrile for GC-MSMS and LC-MSMS analysis. Multi-residue working solutions containing pesticides analyzed by GC-MS/MS and LC-MSMS were prepared in acetonitrile at a concentration of 5 – 100 ppb for each pesticide to create calibration curves.

GC-MSMS Analysis

GC-MS/MS analysis was proceeding using a gas chromatography (GC-MSMS- TSQ9610 Mass Spectrometer, Thermofisher, USA), With Trace gold GC column TG-5MS, length 30 m, internal diameter 0.25mm, film 0.25µm and temperature -60 to 330/350°. Sample injection was performed in the splitless mode, with an injector temperature of 250 °C and an interface temperature of 280 °C. The temperature of the oven was programed from an initial value of 80 °C for 1 min, ramped to 160 °C at 10 °C min^{-1} for 2 min, and to 280 °C at 12 °C min^{-1} for 6 min. Helium was used as a carrier gas with a constant flow rate of 1.2 mL min^{-1}. Electron ionization was used at –70 eV in selective reaction monitoring (SRM) and full-scan modes between 50 m/z and 550 m/z for the detection of different analyses.

LC-MSMS Analysis

LC-MS/MS analysis was proceeding using a liquid chromatography (LC- MSMS-SCIEX QTRAP 4500, Canada), with Synergi 2.5µm fusion – RP100A, LC column 50*2 mm. C-18 analytical column. The sheath gas temperature was kept at 400 °C. Deionized water containing 0.1% formic acid and ammonium formate 5 mM (mobile phase A), and methanol and (5mM) ammonium formate dissolved in deionized water (95:5, v/v) containing 0.1% formic acid (mobile phase B) were used for the gradient program, which started with 100% A for 1 min and was linearly decrease to 0 % A and 100% B over 13 min. then decrease B to 0 % and 100% A over 6 min. The column temperature was kept at 40 °C, and the injection volume was 3µL with a constant flow rate of 0.4 mL_min^{-1}. For each compound, two multi reaction monitoring (MRM) transitions were monitored. The pesticides Propham, Tricyclazole, Cycluron, Carbaryl, Thiabendazole, Promecarb, Propoxur, Linuron, Carbofuran, Bendiocarb, Mevinphors, Ametryn, Dimethoate, Carboxin, 3-Hydroxycarbofuran, Dicrotophos, Primicarb, Forchlorfenuron, Clothianidin, Thiacloprid, Dithofencarb, Chloroxuron, Thiamethoxam, Spiroxamine, Fenoxycarb, Diflubenzuron, Cyazofamid, Benalaxyl, Boscalid, Triflumeron, Propargite, Spiromesifen, Spirotetramat, Dimethomoroph, Rotenone, Spirodiclofen, Flufenoxuron, Indoxacarb, Chlorfluazuron, Spinosad, Spinetoram, and Emamectin benzoate were analyzed with LC-MS/MS. The results of all investigated sample for above 42 pesticides were less than LOQ (5 ppb). The results indicate the safety of organic vegetables and fruits for human health because of no pesticide residue (Willer and Lernoud, 2017; Apaolaza et al., 2018).

Experimental

The analysis precured as shown in the standard method of Britch standard institute (BS EN 15662:2018). Multimethod for the determination of pesticide residues using GC- and LC-based analysis following acetonitrile (Thermofisher) extraction and clean-up by dispersive solid phase extraction (SPE). Modular QuEChERS-method.

Chromatography techniques

GC-MSMS Thermofisher TSQ9610 With Trace gold GC column TG-5MS, length 30 m, internal diameter 0.25mm, film 0.25µm and temperature -60 to 330/350° c. PrO-Analytical Centrifuges.

Data analysis

Statistical comparisons of differences were made by analysis of variance (ANOVA). To compare the means between different treatments concentrations and Pesticide Residues, the Least Significant Difference (LSD) test was conducted at the 0.05 level of probability, the differences between treatments concentrations and Pesticide Residues were designated by different letters. According to (Snedecor & Cochran, 1980). The data was analyzed using (SAS, 2009).

Results

Changes in pesticide residues (Imidacloprid, Fenpyroximate and Lambda-cyhalothrin) of "Sensation" Strawberry fruits in response to used applications of 28-Homobrassinolide were reported in (Table 1, Figure 1, Figure 2 and Figure 3). The data confirmed the previous trend that pesticide residues (Imidacloprid, Fenpyroximate and Lambda-cyhalothrin) were significantly decreased by two applications compared with control. Moreover, the greatest decrease in pesticide residues (Imidacloprid, Fenpyroximate and Lambda-cyhalothrin) were obtained with 28-Homobrassinolide at 0.05 mg/l in both seasons. The use of 28-Homobrassinolide with the lower concentration at 0.025 mg/l was able to cause a significant decrease in pesticide residues (Imidacloprid, Fenpyroximate and Lambda-cyhalothrin) as compared with control.

The influence of pre-harvest treatments of 28-Homobrassinolide on pesticide residues (Difenoconazole, Azoxystrobin and Fludioxonil) of "Sensation" Strawberry fruits whether high or low concentrations were reported in (table 2, Figure 4, Figure 5 and Figure 6). The data showed that pesticide residues Difenoconazole, Azoxystrobin and fludioxonil were disappeared from strawberry fruits samples when applied 28-Homobrassinolide (at 0.05 mg/l) in both seasons. When 28-Homobrassinolide was applied (at 0.025 mg/l), it gave low pesticide residues (Difenoconazole, Azoxystrobin and Fludioxonil) as compared with control.

Table 1. The effect of pre-harvest applications of various 28-Homobrassinolide concentration on Pesticide Residues (Imidacloprid, Fenpyroximate and Lambda-cyhalothrin) of "Sensation" Strawberry fruits during the two seasons 2023 and 2024.

Treatments	Pesticide Residues (active ingredient of pesticides)					
	Imidacloprid (mg/kg)		Fenpyroximate (mg/kg)		Lambda-cyhalothrin (mg/kg)	
	2023	2024	2023	2024	2023	2024
Control	0.023[a]	0.030[a]	0.111[a]	0.121[a]	0.041[a]	0.052[a]
28-Homobrassinolide at 0.025 mg/l	0.010[b]	0.020[a]	0.108[a]	0.100[a]	0.035[a]	0.048[b]
28-Homobrassinolide at 0.05 mg/l	0.005[b]	0.005[b]	0.051[b]	0.048[b]	0.006[b]	0.009[c]
LSD at 0.05	0.008	0.011	0.011	0.051	0.010	0.002

Values in each column when accompanied with similar letters, were not significantly different by using the least Significant Difference at 0.05 for comparing the means.

Table 2. The effect of pre-harvest applications of various 28-Homobrassinolide concentration on Pesticide Residues (Difenoconazole, Azoxystrobin and Fludioxonil) of "Sensation" Strawberry fruits during the two seasons 2023 and 2024.

Treatments	Pesticide Residues (active ingredient of pesticides)					
	Difenoconazole (mg/kg)		Azoxystrobin (mg/kg)		Fludioxonil (mg/kg)	
	2023	2024	2023	2024	2023	2024
Control	0.269[a]	0.254[a]	0.535[a]	0.622[a]	0.012[a]	0.014[a]
28-Homobrassinolide at 0.025 mg/l	0.043[b]	0.114[b]	0.064[b]	0.096[b]	0.005[b]	0.005[b]
28-Homobrassinolide at 0.05 mg/l	0.000[c]	0.000[c]	0.000[c]	0.000[c]	0.000[c]	0.000[b]
LSD at 0.05	0.010	0.010	0.049	0.062	0.003	0.008

Values in each column when accompanied with similar letters, were not significantly different by using the least Significant Difference at 0.05 for comparing the means.

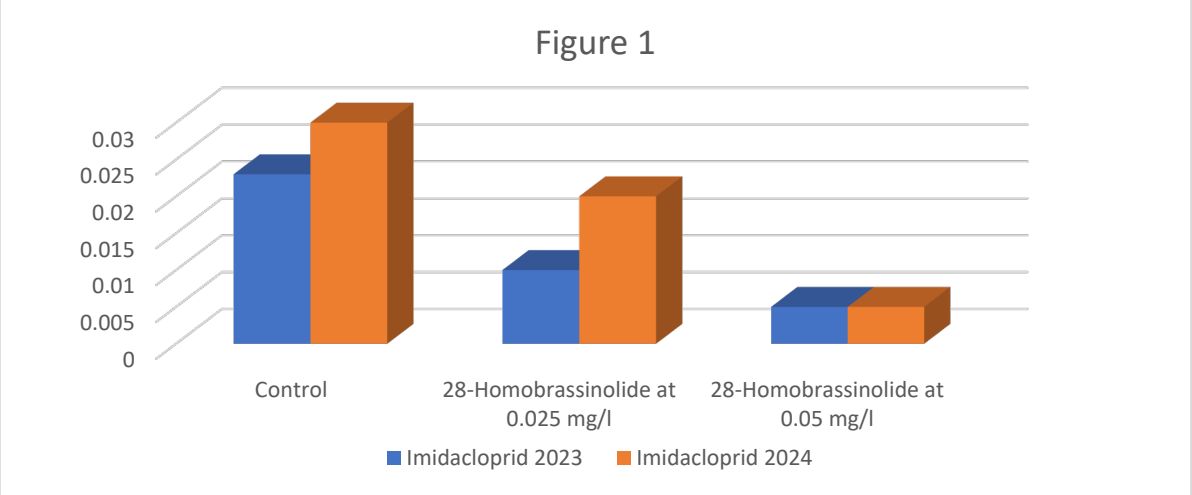


Figure1. Effect of treatments on pesticide residues (Imidacloprid) in both seasons 2023 and 2024.

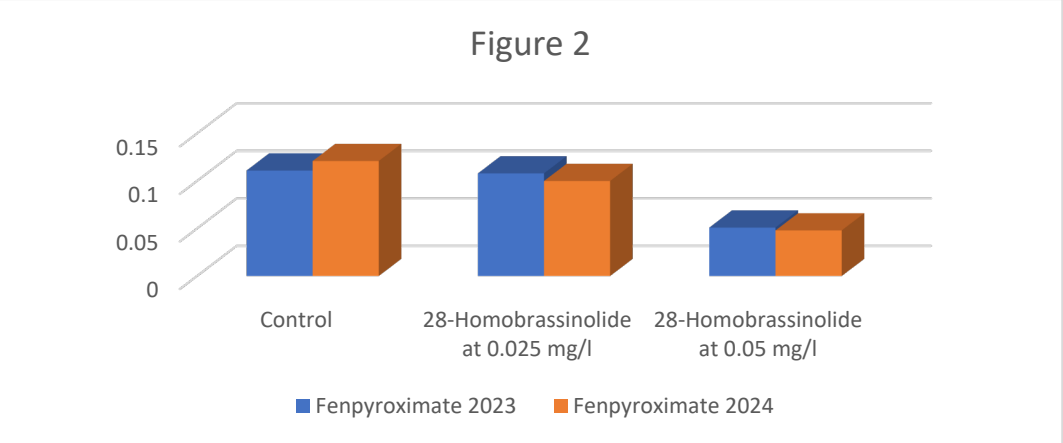


Figure 2. Effect of treatments on pesticide residues (Fenpyroximate) in both seasons 2023 and 2024.

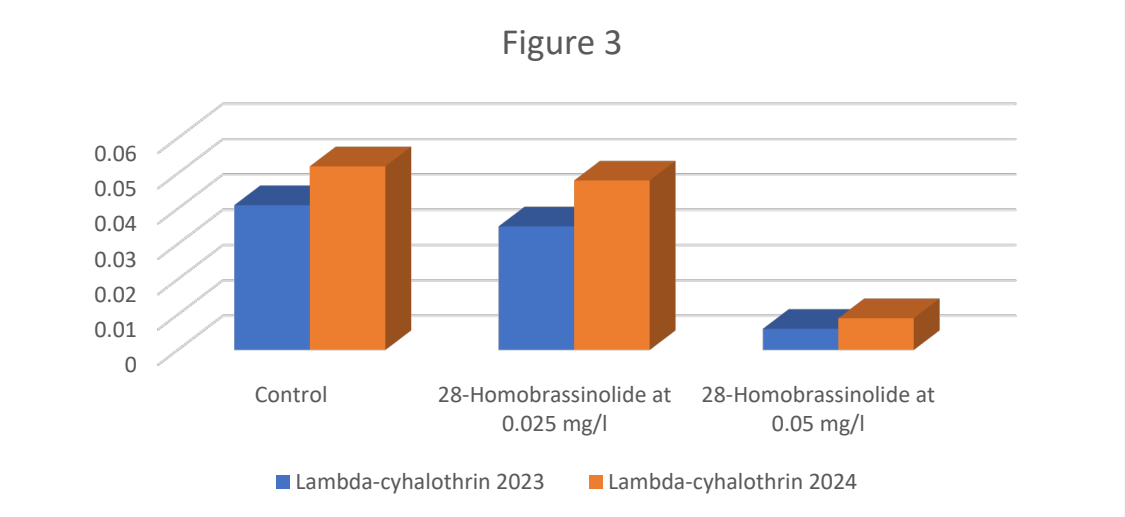


Figure 3. Effect of treatments on pesticide residues (Lambda-cyhalothrin) in both seasons 2023 and 2024.

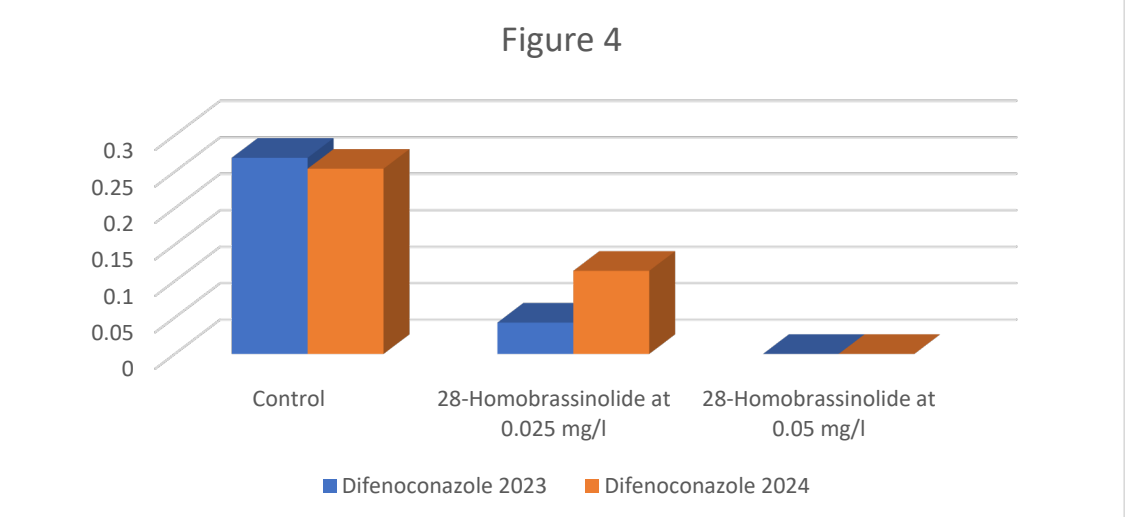


Figure 4. Effect of treatments on pesticide residues (Difenoconazole) in both seasons 2023 and 2024.

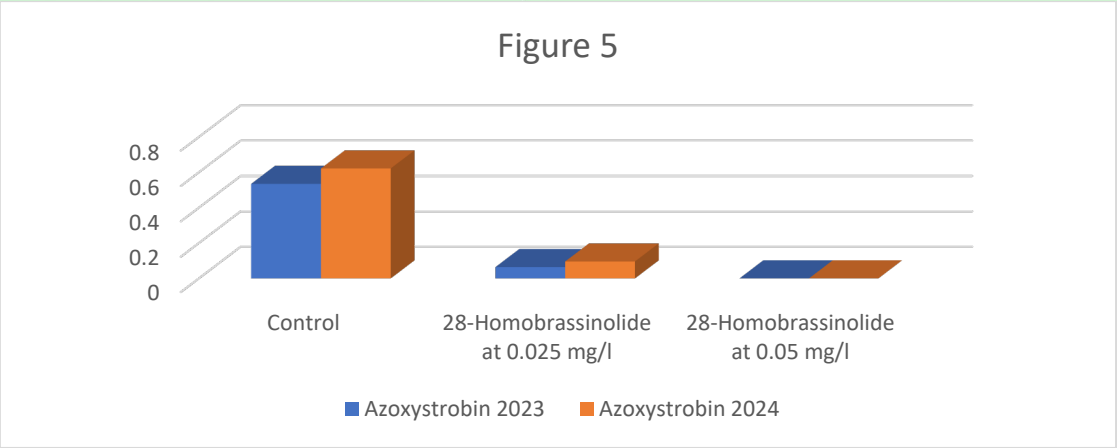


Figure 5. Effect of treatments on pesticide residues (Azoxystrobin) in both seasons 2023 and 2024.

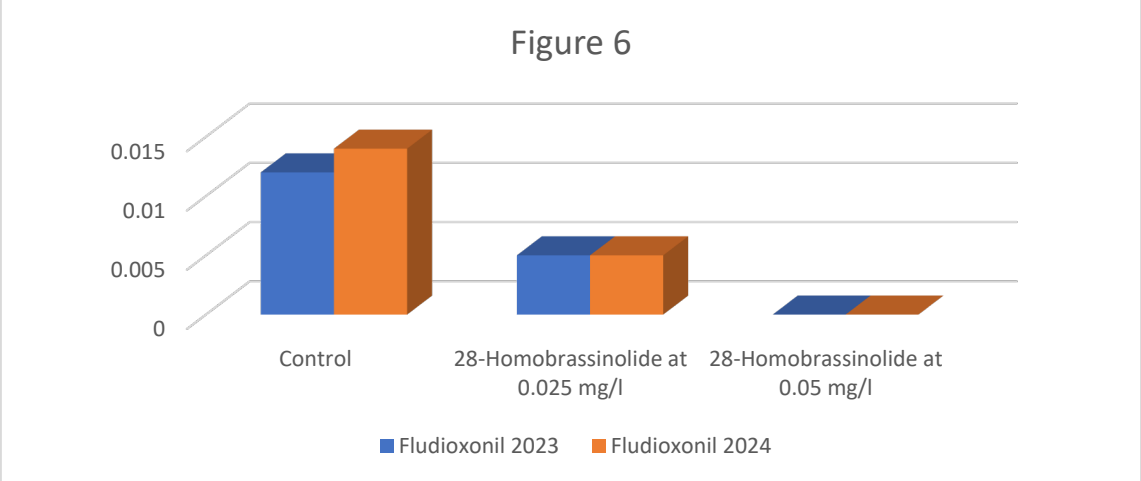


Figure 6. Effect of treatments on pesticide residues (Fludioxonil) in both seasons 2023 and 2024.

Discussion

Brassinosteroids (BRs) have a wide range of biological roles (Nolan et al., 2020; Qiao et al., 2022). 28-Homobrassinolide (HBL) is gaining attention because of its high advantages, such as increasing chlorophyll content and photosynthetic activity, accelerating translocation from source to economic parts. HBL increases the enzyme levels, which are responsible for sugars, proteins and nucleic acid. HBL promotes the proline production, which imparts a greater increase in plants' resistance against adverse weather conditions than other BRs (Sridhara et al., 2021). (Edupuganti et al., 2019) already showed improvement in maize crop growth due to exogenously applied HBL. However, extensive studies with respect to different dosages and application methods were not properly documented, which has played a key role in decreasing the cost and quantity of HBL.

These BRs play important roles in development, plant growth, adaptation to environmental stress and fruit quality (Siddiqi & Husen, 2021; Zhang & Yang, 2021; shehata, 2024). By controlling the antioxidant system, the application of exogenous BRs makes plants more resistant to the toxicity of pesticides (Sharma et al., 2018; Zhou et al., 2015). As an example, pretreatment with 24-epibrassinolide, a BR analogue, can reduce the oxidative stress response in cucumbers (Cucumis sativus) and grapes (Vitis vinifera) brought on by the insecticide chlorpyrifos and (mostly) the fungicide chlorothalonil (Wang et al., 2017; Xia et al., 2006, 2009). In mustard (Brassica juncea), castasterone, a BR, can lessen the insecticide imidacloprid's reactive toxicity (Sharma et al., 2019). Brassinosteroid signalling component (OsBZR4) plays a significant role in atrazine and isoproturon detoxification and metabolism in rice (Su et al., 2024). Yang et al., 2021 indicate that the possible risk of boscalid residue could be alleviated by EBR pretreatment through activating detoxification enzymes. This study provided further evidence about the possibility of utilizing 28-Homobrassinolide, a BR analogue, as a spray treatment to improve detoxification of pesticide residues from fresh strawberry fruits under field conditions.

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ID: 664

Situational Analysis of Kenyan Slaughterhouses in Relation to Resource Utilization. The Case of Nairobi County

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Abstract

The livestock sector plays a vital role in advancing Kenya's Vision 2030, contributing approximately 40% of agriculture's share to the national GDP. Among the key contributors within this sector are slaughterhouses, which generate economically valuable by-products such as hides and skins. This study sought to assess the current utilization of slaughterhouse resources and waste management practices within Nairobi County, with a focus on identifying challenges and opportunities for improved efficiency and value addition.

A descriptive research design was employed, utilizing mixed methods for data collection. Quantitative data from structured questionnaires were triangulated with qualitative insights from focus group discussions, key informant interviews, direct observation, and literature review. Reviewed documents included the Kenya Livestock Sector Report (USAID, 2023), Mapping of Beef Systems in Nairobi Report (Agrisys, 2023), and the Kenya Livestock Market Assessment Report (USAID, 2023).

Findings revealed that while red and green offal are the most commonly sold by-products—averaging KES 350 and KES 170 respectively—market structures remain poorly organized. Only 18% of slaughterhouses sell by-products to established enterprises, with the majority (82%) relying on informal individual buyers. Furthermore, value addition is minimal, with only 46% of facilities utilizing by-products for biogas or animal feed production. The study also highlighted the reliance on outdated equipment and an expressed need among stakeholders for support in acquiring modern technologies.

Overall, the research underscores the untapped potential of slaughterhouse by-products in contributing to Kenya's economic growth. Strategic investment in technology, formal market linkages, and enhanced waste management practices could significantly boost productivity and sustainability within the livestock sector.

ID: 665

Resource Mapping and Economic Potential Assessment of Turkana County, Kenya

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Abstract

This report summarizes a resource mapping study in Turkana County, Kenya, commissioned by the International Labour Organization (ILO) and conducted by the Kenya Industrial Research and Development Institute (KIRDI) under the PROSPECTS programme. The study aims to support social and economic inclusion for refugees and host communities through job creation. Using a mixed-methods approach—desktop research, interviews, focus group discussions, and surveys with 184 stakeholders—the research focused on sub-counties within the PROSPECTS initiative.

Findings reveal that Turkana is rich in resources, with livestock (45%), fisheries (19%), and minerals (11%) being the most prevalent. Seasonal variations affect resource availability, especially in livestock, agriculture, and fisheries. While 49% of producers reported increased availability due to development support, discovery of new resources, high demand, and price increases, 43% reported declines, mainly due to drought. This highlights the need for climate adaptation strategies.

The most traded resources—livestock, fish, agriculture, and charcoal—indicate strong market demand and economic potential. The county government is actively promoting resource development through initiatives in livestock (e.g., slaughterhouse support, dairy goat farming), fisheries (reviving processing facilities, sustainable fishing), and agriculture (irrigation schemes, despite operational challenges).

Key gaps identified include post-harvest losses in fisheries due to limited cold storage, inefficient irrigation systems, and low value addition in forestry. Promising emerging areas include plastic recycling and climate adaptation.

The study recommends further value chain viability assessments, fostering cross-sector collaboration, and establishing a Common Manufacturing Facility (CMF) to boost value addition, productivity, and job creation. Overall, the report provides a strategic foundation for sustainable economic development in Turkana County, offering valuable insights for policymakers, development partners, and local stakeholders.

ID: 667

Field Screening of Rice Genotypes in Drought-prone Rainfed Environment

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Abstract

Rice yield significantly reduced due to drought stress in northwest Bangladesh. Drought-tolerant rice genotypes could play a vital role in increasing rice productivity and sustainability, and improving the livelihood of farmers in drought-prone rainfed ecosystems. Therefore, the study was undertaken to investigate the responses of rice genotypes under drought drought-prone rainfed environment and to select rice genotypes tolerant to drought stress. A total of 30 rice genotypes were evaluated in the drought-prone rainfed high Barind tract at Godagari, Rajshahi, Bangladesh (24.27 N latitude, 88.21 E longitude, 40 masl) over two wet seasons (WS), July to December. Twenty-five-day-old seedlings were transplanted in 25 x 15 cm spacing @ 3 seedlings hill-1 following a randomized complete block design with 3 replications on 16 August of both the WS. Rainfall, temperature, drought severity, groundwater depth, soil moisture content, soil water potential, phenology, leaf rolling and drying, spikelet sterility, dendogram clustering, rooting behaviors, yield, and yield component data were measured to understand drought stress and to evaluate the performance of the genotype. Yield, yield components, leaf rolling, spikelet sterility, and root characteristics varied significantly (p=0.001) among rice cultivars. Grain yield and harvest index of the tested rice genotypes ranged from 1.28 to 4.51 t ha-1 and 0.25 to 0.47, respectively, based on drought severity. Across genotypes, 61% of root biomass was located in the upper 0-10 cm soil layer, and decreased sharply in the layers below (27%, 9%, and 3% in the 10-20, 20-30, and 30-40 cm layers, respectively). Based on overall performance under drought stress, four rice genotypes (IR74371-70-1-1, IR83377-B-B-93-3, IRRI123, and IR83381-B-B-6-1) were selected as drought tolerant, and BR7873-5*(NIL)-51-HR6 was selected as drought escaping. The genotypes IR74371-70-1-1 and BR7873-5*(NIL)-51-HR6 were released as drought-tolerant variety BRRI dhan56 and drought-escaping BRRI dhan57, respectively. Consequently, the genotypic variation in our germplasm selection indicated considerable scope to develop drought-tolerant varieties through breeding to improve rainfed lowland rice.

Keywords: *Drought-tolerance, Leaf Rolling, Spikelet Sterility, Dendogram Clustering, Harvest Index.*

1. Introduction

Drought stress is a serious threat to sustainable rice production worldwide since water resources are limited and good quality irrigation water resources are scarce. However, drought occurrence and its effects on rice productivity often depend more on the rainfall distribution rather than total seasonal rainfall (Hijmans and Serraj, 2008). Intense drought can cause significant damage to the rice crop, often resulting in profound losses impacting farmers' families and the economy (Pandey et al., 2007). In many regions, drought induced losses in crop yields exceed losses from all other stresses, since both its severity and duration are critical (Farooq et al., 2009). The northwest part (Rajshahi region) of Bangladesh is such a drought prone area with low and erratic rainfalls, and limited irrigation potential (Saleh et al., 2000; Saleh and Bhuiyan, 1995). Erratic rainfall distribution causes drought frequently in this region, and results in yield losses that are generally higher than the damage due to flooding and submergence. The recurrent interval of drought is about 2−3 years, and drought occurs especially during the reproductive phase of wet season rice, which is generally classified as terminal drought (Islam, 2007). Often drought is also occurring at the beginning of the wet season, just prior to transplanting of rice seedlings. But apart from these regular events, any growth stage of rice crop can experience intermittent drought during the season due to uneven rainfall patterns (Kamoshita et al., 2008). These conditions are typical for about 0.16 M ha land of northwest Bangladesh which are rainfed and mainly drought prone (Saleh et al., 2000). The major portion of this region is part of the Barind tract which is a distinctive physiographic unit comprising a series of uplifted blocks of undulating terraces. The Barind has a higher elevation than the adjoining floodplain, with two terrace levels, one at 40 masl and another at 20−23 masl (Riches, 2008). Bangladesh as a whole has an average rainfall of about 2300 mm, ranging from 1000 to 5000 mm, but mean annual rainfall is lowest (1000-1200 mm) in the northwestern region (Karmakar et al., 2012; Saleh et al., 2000). Due to the effect of climate change, the weather of this region is getting extremer over the years. Karmakar et al. (2010) reported that only 800 mm rain occurred in Rajshahi during 2009. Annual average rainfall of the Rajshahi region showed a decreasing trend, declining by 3.1 mm per year since the last 50 years (Ferdous and Baten, 2011). Considering these changes occurring, comprehensive research on field screening of rice genotypes were undertaken in the drought prone rainfed environment of northwest Bangladesh.

The wet season (Aman) rice production in Bangladesh is dependent on monsoon rainfall. Farmers largely rely on rainfall and experience late transplanting of Aman rice when the monsoon is delayed, or yield reduction when drought occurs during the booting stage of rice in October. Delayed onset of the monsoon can create water stress for transplanted rice seedlings resulting to lower yields. Water stress due to extended delay of rainfall may even destroy rice seedlings (Mahmood et al., 2003) which is a recurrent phenomenon and an important constraint to rainfed rice production in Asia. However, rice yield is more affected by drought from panicle initiation to the grain filling stage. These stages occur late in the season when the probability of drought is higher than early in the season. Thus, late-season drought has a larger aggregated production impact than early-season drought (Pandey and Bhandari, 2008). Genotypes with increased drought tolerance are considered to be the first necessary step to improve the productivity of drought-prone rice-based systems. Consequently, research efforts were directed for many years towards the development of early-maturing and drought-tolerant rice varieties.

Another important element in drought tolerance are root systems. Rice root systems vary significantly among genotypes and soil conditions in drought prone rainfed environments (ref???). Root characteristics are strongly associated with drought resistance under rainfed conditions (Sharma et al., 1994). The root system of rice cultivars is strongly determined by genetics, however, it also affected by the soil moisture situation and crop management practices (Mambani et al., 1990; Sharma et al., 1987; Cruz et al., 1986). Reports showed that root length density (RLD) in lowland rice is affected by environmental conditions, genotype, management practices and soil depth (Tuong et al., 2002; Samson et al., 2002).

Recent research at the International Rice Research Institute (IRRI) has shown that direct selection for grain yield under drought stress is effective (Bernier et al., 2007; Venuprasad et al., 2007). IRRI and its National Agricultural Research and Extension System (NARES) partners identified several promising breeding lines that can produce 1.0−1.5 t ha^{-1} higher yield than current mega varieties in drought prone environments (Mackill et al., 1996). However, many of these promising genotypes have not yet been tested in drought prone rainfed environments of Bangladesh. But in order to identify the most promising and adaptable genotypes, screening and fine-tuning are required in the target environment. Therefore, a drought screening trial needed to be pursued in the drought-prone rainfed northwest Bangladesh. The main purposes of this study were to evaluate the performance of rice genotypes in drought-prone rainfed environment, and to select rice genotypes for drought tolerance based on root index and overall performance.

2. Materials and methods

2.1 Experimental site

The experiments were conducted in a farmer's field at Edulpur, Godagari, Rajshahi, Bangladesh (24°27′N latitude, 88°21′ E longitude, 43 masl) during the 2009 and 2010 wet season (WS). A drought prone rainfed topmost field in the *Barind tract* was selected for the experiment. The experimental site belongs to the Agro-ecological Zone (AEZ) 26, having silt loam to silty clay soils with a grey color (BARC, 2018). The topsoil at the experimental site had a soil pH of 5.8, a texture of 17% clay - 68% silt - 15% sand, soil organic carbon of 0.70%, total soil N of 0.078%, a C/N ratio of 9.0, available P_{Olsen} of 10.0 mg kg^{-1}, exchangeable $K_{exch.}$ of 0.21 me/100 g and a cation exchange capacity (CEC) of 6.8 cmol kg^{-1}.

2.2 Background of the tested rice genotypes

Thirty rice genotypes including 4 check varieties were tested for drought tolerance in the drought-prone rainfed conditions (Table 1). The rice genotypes were collected from the International Rice Research Institute (IRRI), the Bangladesh Rice Research Institute (BRRI), the Bangladesh Institute of Nuclear Agriculture (BINA) and farmers. IRRI and NARES partners identified several promising breeding lines that can produce 1.0–1.5 t ha^{-1} higher yield than current mega varieties under drought stress (Mackill et al., 1996). Some of the breeding lines were developed following crosses between two drought-tolerant breeding lines with the aim to accumulate positive alleles for drought tolerance from the two parents. Another set of breeding lines were developed by crossing drought-tolerant breeding lines with high-yielding popular drought-susceptible lines, with the aim to develop drought-tolerant breeding lines with high yield potential and good grain quality. All crosses were advanced through cyclic selection under reproductive stage drought stress from F_2 to F_6 generations based on drought tolerance, high yield, insect and disease tolerance, and good grain quality traits (amylose content, chalkiness etc.). The F_6 generation was transplanted under reproductive stage drought and selection was carried out in the nurseries. High-yielding lines under drought stress were bulked and forwarded to the observational yield trial (OYT). In the OYT, selection for high yield was repeated under reproductive stage drought stress and the best lines were forwarded to the advanced yield trials (AYT). In the AYT, selected lines were again tested with drought imposition at the reproductive stage. Selected drought tolerant genotypes from IRRI Philippines were then brought to Bangladesh for field screening in drought prone rainfed environments. Since there was no existing drought tolerant rice variety, 4 promising rice varieties were used as checks in the screening experiments.

Table 1. Rice genotypes tested in the experiments

SN	Rice genotype	Parentage (Male parent/Female parent)
1	IR83376-B-B-71-1	IR71700-247-1-1-2 (DT)/IR77080-B-34-1-1 (DT)
2	IR83381-B-B-137-1	IR72022-46-2-3-3-2 (DT)/IR77080-B-34-1-1 (DT)
3	IR83373-B-B-25-3	IR71700-247-1-1-2 (DT)/IR72875-94-3-3-2 (DT)
4	IR83376-B-B-130-2	IR71700-247-1-1-2 (DT)/IR77080-B-34-1-1 (DT)
5	IR83381-B-B-6-1	IR 72022-46-2-3-3-2 (DT)/IR 77080-B-34-1-1 (DT)
6	IR83372-B-B-33-2	IR 71700-247-1-1-2 (DT)/IR 57514-PMI 5-B-1-2 (DT)
7	IR83381-B-B-55-4	IR72022-46-2-3-3-2 (DT)/IR77080-B-34-1-1 (DT)
8	IR83373-B-B-81-2	IR71700-247-1-1-2 (DT)/IR 72875-94-3-3-2 (DT)
9	IR83383-B-B-141-2	IR72022-46-2-3-3-2 (DT)/IR57514-PMI 5-B-1-2 (DT)
10	IR83376-B-B-150-1	IR 71700-247-1-1-2 (DT)/IR77080-B-34-1-1 (DT)
11	IR83376-B-B-110-2	IR 71700-247-1-1-2 (DT)/IR77080-B-34-1-1 (DT)
12	IR83376-B-B-24-2	IR 71700-247-1-1-2 (DT)/IR77080-B-34-1-1 (DT)
13	IR83383-B-B-129-4	IR 72022-46-2-3-3-2 (DT)/IR 57514-PMI 5-B-1-2 (DT)
14	IR74371-70-1-1	IR 55419-4*2 (DT)/WAY RAREM (DS)
15	IR83387-B-B-27-4	IR 72022-46-2-3-3-2 (DT)/SAMBHA MAHSURI (DS)
16	IR83614-427-B	IR 78875-131-B-1-2 (DT)/IR 64 (DS)
17	IR83388-B-B-108-3	IR 72022-46-2-3-3-2 (DT)/SWARNA (DS)
18	IR83377-B-B-93-3	IR 71700-247-1-1-2 (DT)/SAMBHA MAHSURI (DS)
19	IR83388-B-B-8-3	IR 72022-46-2-3-3-2 (DT)/SWARNA (DS)
20	IR83387-B-B-134-2	IR 72022-46-2-3-3-2 (DT)/SAMBHA MAHSURI (DS)
21	IRRI123	IR 47761-27-1-3-6 (DT)/IRRI 108 (DS)
22	IR83377-B-B-48-3	IR 71700-247-1-1-2 (DT)/SAMBHA MAHSURI (DS)
23	IR78937-B-3-B-B-1	IR 47701-6-B-1 (DS)/IR 55435-05 (DT)
24	BR7870-5*(Nils)-8-HR4	BR10 (DS)/5*CR146-7027-224 (DT)
25	BR7873-5*(NIL)-51-HR6	BR11 (DS)/5*CR146-7027-224 (DT)
26	NERICA4	WAB 56-104 (DT)/CG 14 (DS)
27	IR64 (Check)	IR 5657-33-2-1 (DT)/IR 2061-465-1-5-5 (DS)
28	Binadhan-7 (Check)	TNDB100/ Kienguyen
29	BRRI dhan49 (Check)	BR4962-12-4-1/IR33380-7-2-1-3
30	Guti Swarna (Local check)	Popular variety of northwest Bangladesh

NB: SN-Serial number, DT-Drought tolerant and DS-Drought susceptible

2.3 Experimental protocol and management practices

Seedlings were raised in a seedbed according to the traditional farm practice. Seeds were soaked in water for 24 h and incubated until the radicle emerged. Sprouted seeds were broadcasted at 80 g m^{-2} on 22 July of the two successive wet seasons 2009 and 2010. Fertilizers containing N, P, K and S at 46, 20, 30 and 18 kg ha^{-1}, respectively, were applied in the seedbed during final land preparation (BRRI, 2019). Urea (N at 46 kg ha^{-1}) was top dressed at 10 days after seeding (DAS). Wet land soil preparation with puddling was done according to the common practice. Initially, the land was ploughed once with a country plow, followed by two power tiller passes and laddering. After 7 days, the land was finally prepared by one pass with a power tiller, followed by laddering to level the land. The levee around the plot was newly made. Fertilizers used were urea, TSP, MOP, gypsum and zinc sulfate, applied at a rate of N, P, K, S and Zn of 82, 15, 38, 10.6 and 2.7 kg ha^{-1}, respectively. The full amount of TSP, MOP, gypsum, zinc sulfate and one-third of the urea were applied basally during the final land preparation. The remaining urea was top-dressed in two equal splits at 20 days after transplanting (DAT) and 40 DAT synchronized with rainfall or wet soil conditions as the experiment was conducted under rainfed conditions. The experiment was laid out following a randomized complete block design with 3 replications. Twenty five-day-old seedlings were transplanted with a 25 x 15 cm spacing (BRRI, 2019) at 3 seedlings $hill^{-1}$ on 16th August in both years. Transplanting of rice seedlings purposely delayed from optimum planting (July) to address terminal drought at reproductive stage. Unit plot size was 2.5 m x 4 m. Based on the drought characteristics of the experimental site, transplanting was purposively delayed compared with the normal transplanting time (July) of Aman rice (wet season) to increase the potential exposure to drought stress (Torres et al., 2012). The levee around the experimental plots was opened at 28 DAT to ensure severe drought stress at reproductive stage of the crop. Uniform and standard management practices were followed to control weed and pest in the plots.

2.4 Sampling and data collection

Recommended procedures were followed to collect data for yield and yield components, agronomic parameters, and drought stress measurements (Gomez, 1972; Gomez and Gomez, 1984; IRRI, 2002; IRRI, 1994). At maturity, tillers and panicles $hill^{-1}$, empty and full spikelets $hill^{-1}$, and 1000-grain weight were counted from 2 x 2 hill

sampling units from three places (12 hills plot^{-1}) sampled on a diagonal in each plot (Gomez, 1972). From the center of each plot, 6-m^2 areas were harvested for determination of grain and straw yields at maturity. After harvest and threshing, grains were sun-dried, and weight and moisture content were measured. Grain yield was adjusted to 14% moisture content, and expressed in t ha^{-1}.

2.5 Climate monitoring and drought stress characterization

Meteorological data (daily rainfall, air temperature, evaporation and sun shine hour) were collected from the mini-weather station at Edulpur, Godagari, Rajshahi, Bangladesh set up by BRRI Rajshahi and very close (25 m) to the experimental plots.

2.6 Rainfall status

The experimental site at Edulpur, Godagari, Rajshahi received the lowest seasonal rainfall (744 mm) since a decade in the year 2009. Of the total, 210 mm occurred in August, which also had 17 rainless days (Fig.1). In September, rainfall was 181 mm but 80% of that occurred in the 1st half of the month and 21 days were rainless. There were 27 rainless days in October and only 15.8 mm rainfall was observed (Fig. 1). Consequently, the crop of 2009WS experienced severe drought stress during the reproductive phase. In contrast, 897 mm rain occurred at the experimental site in the WS 2010 of which 115, 160, 192, 133 and 2.4 mm rain occurred in July, August, September, October and November, respectively (Fig. 2). Rainfall from July to October 2010 was well distributed (Fig. 2). Therefore, especially the short and medium duration genotypes did not face drought stress in the 2010WS. However, the long duration genotypes flowering after the 3rd week of October experienced medium drought stress.

2.7 2Temperature status

Monthly mean temperatures from July to November of 2009 were comparatively higher than in 2010. Temperature fluctuation of both years followed similar trends, but the day-night temperature difference in October to November 2009 was higher than in 2010. Monthly mean maximum and minimum temperatures at the site from July to November were 32.1 and 20.5 °C in 2009, and 29.4 and 25.2 °C in 2010. The mean daily sunshine duration was 6.14 h in the 2009WS and 5.65 h in the 2010WS.

2.8 Drought measuring protocol

Drought stress was assessed indirectly by measuring soil moisture content, soil water potential, drought amount quantification, leaf rolling and drying score, spikelet sterility percentage, phenotypic acceptability and root characteristics. The methods are outlined below.

2.9 Ground water depth measurement

Ground/perched water table was monitored daily with Polyvinyl chloride (PVC) pipe/ piezometers of 1 m length and 0.05 m diameter. The lower 0.8 m end of the pipe, which was below ground, was perforated with 4 mm holes. Three PVC pipes were installed in the experimental plots and the water level was regularly monitored in relation to the upper end of the pipe. Water table depth in the experimental field fell sharply from 13th September onward in the 2009 WS (Fig. 3). It reached 0.8 m below ground on the 25th September and stayed there until the end of the 2009 season. In the 2010 WS, the perched water table started to fall from the 27th September but fell slowly. This confirmed that the 2009 WS experienced a severe drought while the 2010-WS was only a moderately drought for the crop.

2.10 Soil moisture content measurement

The levee surrounding the plots was cut at 28 DAT, so that the soil dried faster during rainless days. Cracks developed in the soil of the plots quickly and became deeper during the season. Three soil samples from 0-0.2 m depth of each replication were taken by auger twice weekly from 30 DAT until the ripening stage. After recording the initial weight, the soil samples were wrapped in aluminum foil and oven dry weight was determined after drying at 70 ˚C temperature for 72 h. Initial and oven dry weight of the soil samples were used to calculate soil moisture content as a measure of soil water status in the field. Soil moisture content was calculated using the following formula:

$$\text{Soil moisture content (\%)} = \frac{\text{W1-W2}}{\text{W1}} \times 1 - W \qquad (1)$$

where W1 is the initial weight of the sample and W2 is the oven dried weight of the sample.

Soil moisture status of the experimental plots during the seasons is shown in Fig.4. In general, soil moisture during the 2009 WS was much lower than in the 2010 WS. It decreased to 8% at the last week of October during 2009 WS while it was still 20% at the end of the 2010 WS.

2.11 Soil water potential measurement using Tensiometer

Soil water potential measured with tensiometers (give specs of the equipment used???) after draining the plots at 28 DAT in both seasons is shown in Fig. 5. The soil water potential declined generally but fluctuated up and down in both early seasons due to alternating periods of drought and rainfall (Fig. 5). Fluctuating soil water potentials continued longer in the 2010 WS. A steady decline started from 7th October 2009 but only the 17th October 2010.

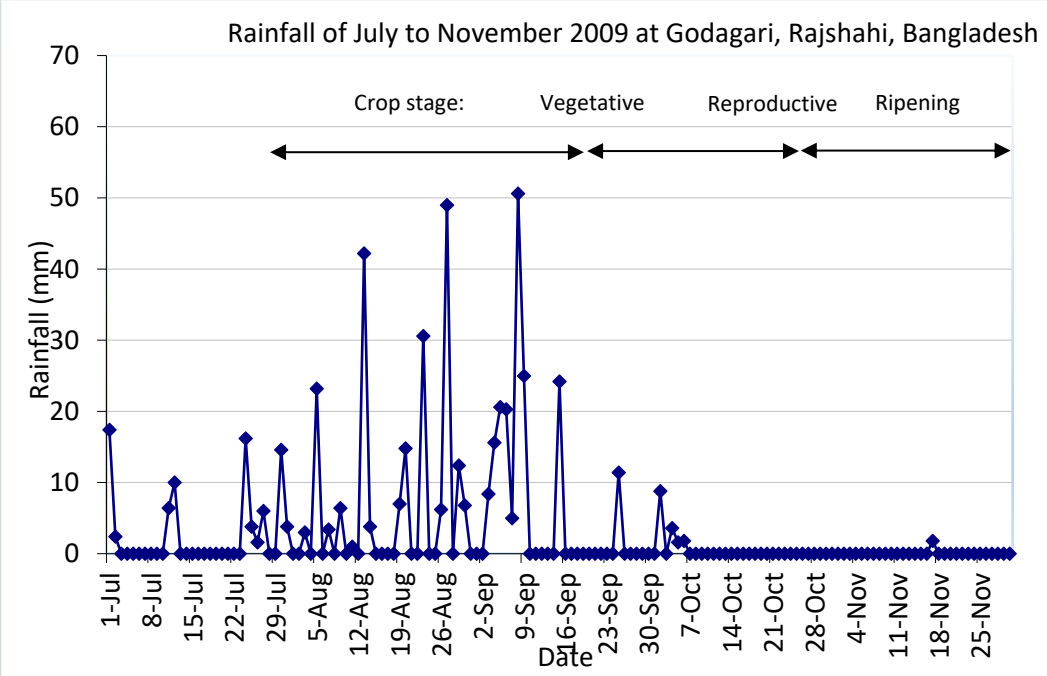


Figure 1. Crop stage and rainfall distribution at the experimental site during July-November 2009 (Source: Mini weather station of BRRI Rajshahi at Godagari, Rajshahi, Bangladesh).

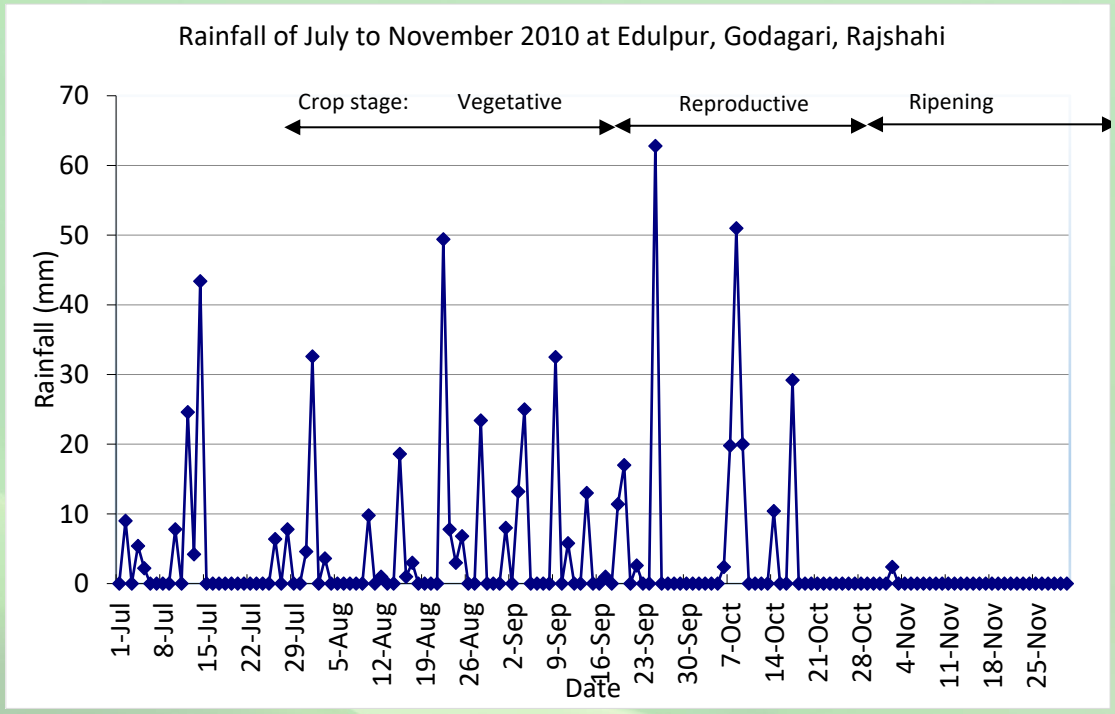


Figure 2. Crop stage and rainfall distribution at the experimental site during July-November 2010 (Source: Mini weather station of BRRI Rajshahi at Godagari, Rajshahi, Bangladesh).

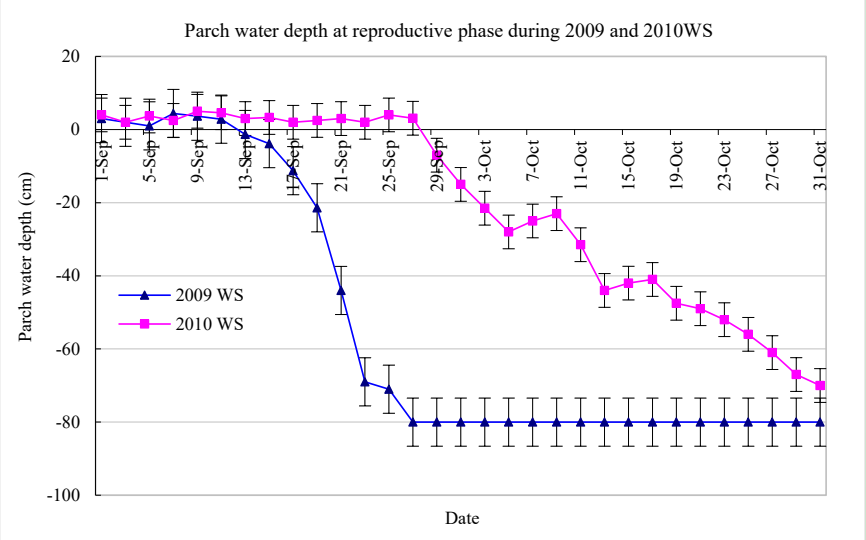


Figure 3. Parch water depth at the experimental field during 2009WS and 2010WS at Godagari, Rajshahi, Bangladesh.

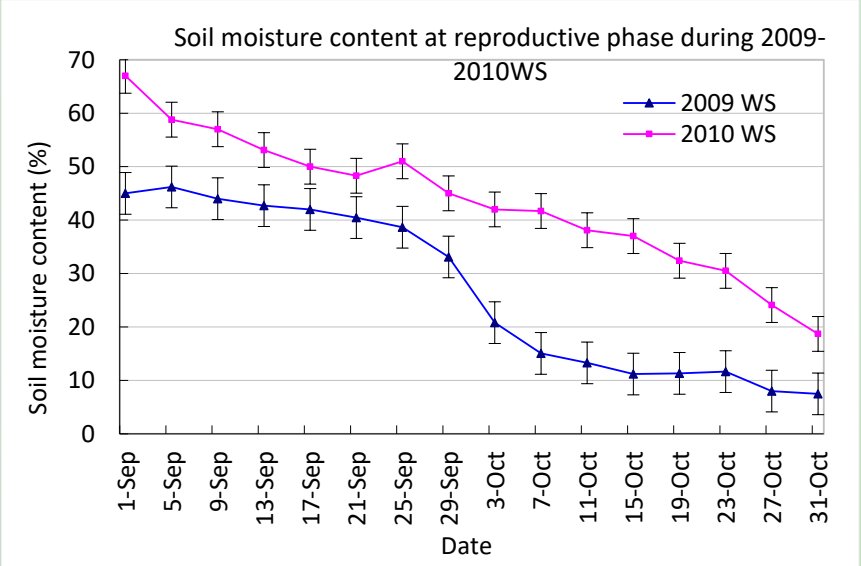


Figure 4. Soil moisture content at the experimental fields during 2009WS and 2010WS at Godagari, Rajshahi.

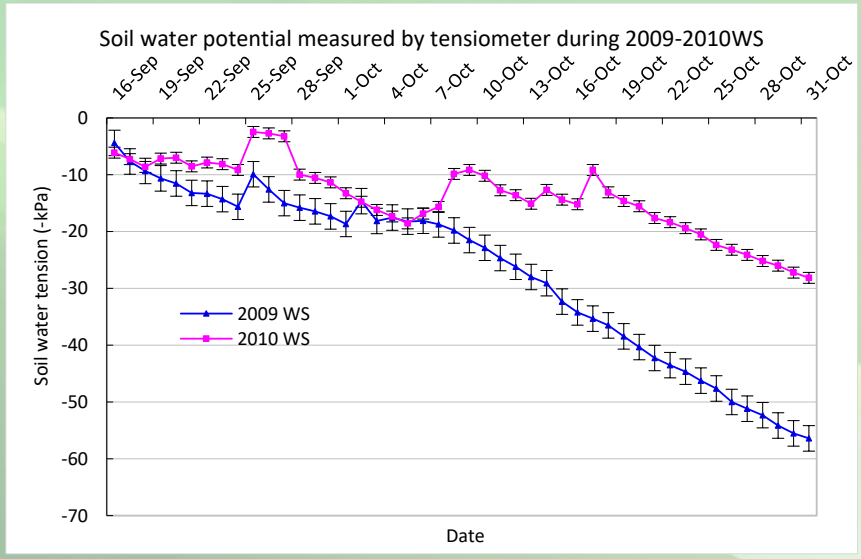


Figure 5. Soil water potential at the experimental fields during 2009WS and 2010WS at Godagari, Rajshahi, Bangladesh.

2.12 Drought Severity quantification

Drought Severity was determined using Drought Simulation Model (Islam et al., 2007) and expressed in water deficit compared to a simulated normal watered crop. Drought severity was considered as the water deficit in the soil being equal to the unfulfilled demand of a simulated normal crop and drought duration was the period of time during which the crop suffered from drought. Drought severity was the cumulative amount of drought for that duration. Based on the seeding and transplanting date of the crop in 2009 and 2010WS, drought amount and duration were quantified in three crop stages like vegetative (08 August to 15 September), reproductive (16 September to 15 October) and ripening stage (16 October to 15 November). The model assumes two storages of water; the first one is called surface water storage (SWS) and the second one is soil moisture storage (SMS). SWS contain standing water in the field above the soil surface and SMS contains soil moisture in the root zone soil. The ET demand of crop is met from the first storage (SWS) if there is water in it on the dry days. When first storage is exhausted then ET demand is met from the second storage (SMS). If the SMS is unable to satisfy ET demand in the continued dry period, and the crop experiences drought stress. The amount of drought is considered to be equal to ET demand that remains unfulfilled due to inadequate moisture in the soil.

2.13 Leaf-rolling and Leaf-drying

Drought sensitivity of the germplasm tested was measured through scoring of leaf rolling and drying during the vegetative and reproductive stage of the crop following the protocol developed by IRRI, using a score between 0 (leaves healthy; no rolling) and 9 (leaves tightly rolled) (IRRI, 2002).

2.14 Spikelet fertility and sterility

Drought stress was also measured indirectly through the level of spikelet sterility, using a score between 1 (less than 20% sterility) and 9 (more than 90%) (IRRI, 2002).

2.15 Root Biomass

Roots from the depth of 0-10, 10-20, 20-30 and 30-40 cm were collected during harvest, by soil core sampler (10 cm diameter auger) from the center of a hill and 5 cm apart from the center of hills with average tiller number (Karmakar et al., 2004). The soil core sampler was placed on the soil surface and hammered in to 40 cm depth (Uddin et al., 2009). Five samples were taken from each plot. After sampling, soil cores were divided into 0-10, 10-20, 20-30 and 30-40 cm layers with a knife. Each layer was kept on an iron net (2 mm mesh) and the roots were separated from soil by applying water. After washing each sample was spread out and root length was measured with a Comair Root Length Scanner (Hawker De Havill and Victoria Ltd., Australia). After root length scanning, root samples were dried in an oven at 70 $^{\circ}$C for 48 hours (Henry et al., 2012; Uddin et al., 2009; Karmakar et al., 2004). A high precision balance (milligram) was used to measure the dry weight of root biomass.

2.16 Statistical analysis

Data recorded in the experiments were statistically analyzed following procedures described by Gomez and Gomez (1984). Analysis of variance (ANOVA) was conducted using statistical software CropStat 7.2, cluster constructed by JMP 7.0.2 based on phenotypic characteristics and diversity analyses were done by GenStat 5.3. Means were compared with the least significant difference (LSD) test.

3. Results and Discussion

3.1 Drought severity and drought duration quantification

The genotype screening experiment was conducted under rainfed conditions and the bund was cut at 28 days after transplanting (DAT). Consequently, the crop was fully depended on rainfall. The crop of the wet season 2009 received rains up to the vegetative stage while the crop of 2010 received rainwater up to reproductive stage. Therefore, drought severity and drought duration were higher in 2009 WS than in the 2010 WS. Drought severity at vegetative, reproductive and ripening stage in 2009 was 2, 93 and 152 mm water deficit, respectively while it was 9, 22 and 76 mm water deficit in 2010 WS (Fig. 6). Accordingly, the total water deficit (247 mm) was remarkably higher during in 2009 WS than 2010 WS (107 mm). For drought duration, the data followed the trend of drought amount. Drought duration at vegetative, reproductive and ripening stage was 1, 22 and 20 days in 2009 but it was 3, 8 and 14 days in 2010 WS. Therefore, the crop of the 2009 WS faced 43 days drought stress whereas the stress duration was only 25 days in 2010 WS. Consequently, the crop of the 2009 WS experienced a severe drought stress while it faced moderate drought stress in the 2010 WS.

3.2 Genotype clustering through dendogram regarding leaf rolling and drying, spikelet sterility; and phenotypic acceptability

A dendogram was constructed using a distance matrix which was calculated from phenotypic acceptability, leaf-rolling, leaf-drying and spikelet fertility values. This dendogram determined the relationship among the tested 30 rice genotypes and grouped them into 3 clusters (Fig. 7). The distribution pattern indicated that cluster I comprised the highest number of tested entries (22), followed by cluster II (2), and cluster III (6) (Table 2). Among the clusters, genotypes in cluster III had the highest score having lowest values of phenotypic acceptability, leaf rolling, leaf drying and spikelet sterility scores, indicating that these genotypes possess more drought tolerance compared to other clusters. In contrast, the mega varieties BRRI dhan49 and Guti Swarna were placed in cluster II which showed more susceptibility to drought stress. Cluster I showed intermediate drought tolerance, having values of the parameters

phenotypic acceptability, leaf-rolling, leaf-drying and spikelet fertility in between cluster II and III. Cluster mean of 30 rice genotypes was the highest (8.167) in phenotypic acceptability at the reproductive stage ranging from 1.267 to 8.167 (Table 3). Differences in cluster means existed for almost all the characters studied. Inter and intra cluster distance varied from cluster to cluster (Table 3). Inter cluster distance was the highest (10.936) in between cluster II and III that was followed by cluster I and III (7.245) and the lowest was in cluster I and II (5.952). Intra cluster distances were calculated from the value of distance matrix of tested 30 rice genotypes. Genotypes in cluster I showed the highest intra cluster distance (0.745), followed by cluster III (0.615) and cluster II (0.382). Relative contribution towards divergence is presented in Table 4. Among characteristics for drought tolerance, the value of phenotypic acceptability at vegetative, leaf-rolling and leaf-drying at vegetative and reproductive stage of the genotypes showed positive divergence in vector I (Table 4). It indicated that these characters contributed more towards divergence among the genotypes. In contrast, the values of phenotypic acceptability at vegetative stage and spikelet sterility were negative in vector I contributed less toward divergence. All the parameters scored at reproductive stage showed positive value in vector-II while it was negative in case of scored recorded at vegetative stage (Table 4). The double positive values generally contributed higher in divergence. In the present study, three characters such as phenotypic acceptability, leaf-rolling and leaf-drying at reproductive stage showed double positive value in both the vectors indicated that those characters contributed most towards divergence. In contrast, single character phenotypic acceptability at vegetative showed double negative value in both the vectors. Spikelet sterility showed positive value in vector-II and negative value in Vector-I indicated that it also contributed remarkably for divergence.

3.3 Genotypic variation on yield, yield attributes and agronomic parameters under drought stress

Significant genotypic difference existed among the rice cultivars for grain yield, yield components and agronomic parameters in both the 2009 and 2010WS (Table 5). Across the genotypes, IR83377-B-B-93-3 attained the highest grain yield (3.65 t ha^{-1}) followed by IRRI 123 (3.53 t ha^{-1}) and IR74371-70-1-1 (3.52 t ha^{-1}) in 2009WS under severe drought stress. Quite the reverse, locally popular mega variety Guti Swarna produced the lowest grain yield (1.30 t ha^{-1}) followed by BRRI dhan49 (1.36 t ha^{-1}). The genotype NERICA4 gave 2.10 and 2.71 t ha^{-1} grain yield during 2009 and 2010WS, respectively. In general, yield of the tested genotypes was lower in 2009WS than 2010 WS as the crop of 2009 WS faced more drought stress at reproductive phase compared to 2010 WS (Fig. 6).

Grain yield ranged from 1.28 to 3.65 t ha^{-1} in 2009WS while it was 2.44 to 4.51 t ha^{-1} in 2010WS. Similarly, percentage of grain yield reduction in 2009 over 2010 ranged from 14 to 57.0% (Table 5). Grain yield reduction was the highest (57.0%) in the Guti Swarna while the lowest (14%) was in IR74371-70-1-1 followed by IR83377-B-B-93-3 (19%) and IRRI 123 (20%) in 2009WS over 2010WS. In general, harvest index was lower than the optimum level of high yielding variety and it was also lower in 2009WS than 2010WS. Across the genotypes and years, most of the genotypes contained lower harvest index with an average of 0.37 ranging from 0.25 to 0.45 in 2009WS while it was 0.41 ranging from 0.33 to 0.47 during 2010WS. Harvest index was the highest (0.45) in IR83377-B-B-93-3 followed by IR74371-70-1-1 (0.44) and IRRI (0.44) in 2009WS. It was the lowest (0.25) in Guti Swarna in 2009WS while it was the lowest (0.27) in BRRI dhan49 in 2010WS. Days required to maturity and plant height remarkably affected by the genotypes (Table 5). Days to maturity ranged from 102 to 134 during 2009WS while it was 105 to 136 days in 2010WS. In general, soil water tension was higher in 2009WS compared to 2010WS (Fig. 5).

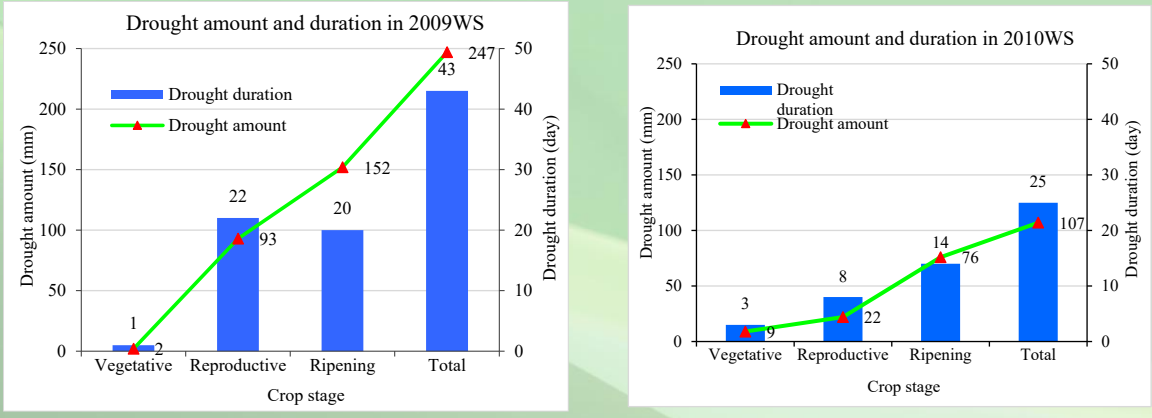


Figure 6. Drought amount and drought duration in the experimental field during 2009 and 2010WS at Godagari, Rajshahi, Bangladesh.

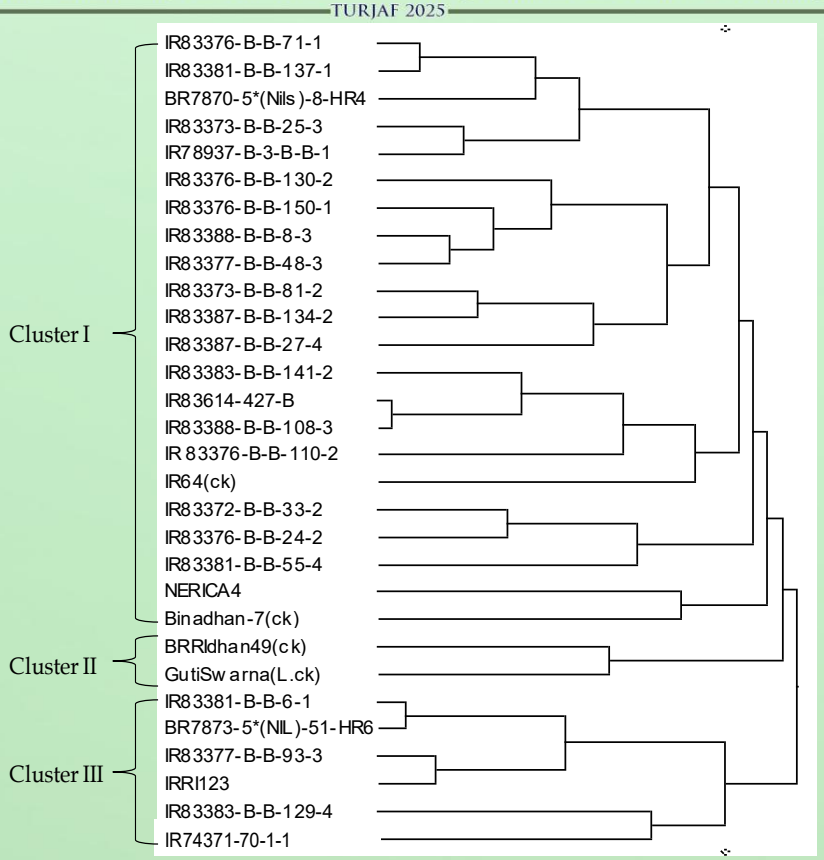


Figure 7. Dendogram of 30 rice genotypes based on phenotypic acceptability, leaf rolling, leaf drying and spikelet fertility under drought prone rainfed environment.

Table 2. Intra-cluster (Diagonal) and inter-cluster (D^2) divergence values of 30 rice genotypes.

Clusters	Cluster I	Cluster II	Cluster III
Cluster I	**0.745**		
Cluster II	5.952	**0.382**	
Cluster III	7.245	10.936	**0.615**

NB: Bold figures denote intra cluster distance

Table 3. Cluster means of the characteristics of 30 rice genotypes.

Characteristics	Cluster mean		
	I	II	III
Phenotypic acceptability at vegetative stage	3.887	6.189	2.333
Phenotypic acceptability at reproductive stage	6.133	8.167	2.550
Leaf rolling at vegetative stage	1.778	1.953	0.200
Leaf rolling at reproductive stage	3.900	4.044	1.267
Leaf drying at vegetative stage	1.533	1.589	0.267
Leaf drying at reproductive stage	3.444	3.993	1.433
Spikelet fertility	4.511	4.560	3.667

Table 4. Characters contribution towards divergence among the 30 rice genotypes.

Characteristics	Vector I	Vector II
Phenotypic acceptability at vegetative stage	-0.0511	-0.7070
Phenotypic acceptability at reproductive stage	0.2904	0.1821
Leaf rolling at vegetative stage	0.5026	-0.9340
Leaf rolling at reproductive stage	0.1956	0.2377
Leaf drying at vegetative stage	0.6383	-1.7975
Leaf drying at reproductive stage	1.2135	0.9422
Spikelet fertility	-0.2526	0.3186

Table 5. Phenology, yield and yield components of the rice genotypes under drought prone rainfed environment at Godagari, Rajshahi Bangladesh during 2009 and 2010WS.

Genotype	Grain yield (t ha^{-1})		Yield reduction (%) in 2009 over 2010	Harvest Index		Growth duration (day)		Plant height cm)		Panicles m^{-2} (no.)		Sterility (%)		1000-grain wt. (g)	
	2009	2010		2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
IR 83376-B-B-71-1	1.68	2.92	43	0.34	0.40	110	112	102	104	190	206	46	38	22.6	23.5
IR 83381-B-B-137-1	1.87	3.02	38	0.36	0.41	111	113	103	105	192	212	45	39	23.1	23.8
IR 83373-B-B-25-3	1.50	2.57	42	0.31	0.38	109	111	108	109	187	203	47	40	22.8	23.3
IR 83376-B-B-130-2	2.20	3.12	29	0.37	0.39	109	110	106	107	201	226	38	35	22.7	23.2
IR 83381-B-B-6-1	3.11	4.07	22	0.41	0.43	108	110	104	109	212	235	29	24	23.3	23.7
IR 83372-B-B-33-2	1.46	2.58	44	0.33	0.36	107	109	95	97	188	210	51	41	22.7	23.4
IR 83381-B-B-55-4	1.35	2.38	43	0.31	0.37	110	113	104	106	174	190	52	43	22.3	23.2
IR 83373-B-B-81-2	1.89	3.01	37	0.36	0.41	105	108	95	96	196	220	45	40	22.6	22.9
IR 83383-B-B-141-2	2.55	3.78	33	0.41	0.45	108	111	102	104	213	233	35	30	22.9	23.3
IR 83376-B-B-150-1	2.35	3.25	26	0.39	0.41	109	110	108	111	206	222	37	32	23.2	23.5
IR 83376-B-B-110-2	2.76	3.87	29	0.43	0.46	111	113	103	105	220	242	34	29	22.7	23.5
IR 83376-B-B-24-2	1.41	2.44	42	0.30	0.35	109	111	92	93	167	199	52	42	22.4	22.7
IR 83383-B-B-129-4	2.91	3.92	26	0.42	0.46	113	115	103	108	220	233	31	27	23.0	23.3
IR74371-70-1-1	3.52	4.11	14	0.44	0.47	105	108	106	110	228	251	26	23	23.2	23.4
IR 83387-B-B-27-4	2.14	3.07	30	0.36	0.39	111	114	92	97	213	229	42	37	23.8	24.3
IR83614-427-B	2.28	3.17	27	0.37	0.40	103	105	87	90	219	235	41	35	22.5	23.2
IR 83388-B-B-108-3	2.37	3.41	31	0.39	0.42	109	112	100	104	217	235	37	31	22.7	23.2
IR 83377-B-B-93-3	3.65	4.51	19	0.45	0.47	112	115	103	110	245	261	26	22	23.3	23.6
IR 83388-B-B-8-3	2.36	3.26	28	0.37	0.40	112	115	103	106	213	231	43	34	22.6	23.4
IR 83387-B-B-134-2	2.17	3.08	29	0.35	0.38	113	116	102	107	197	217	44	35	22.9	23.4
IRRI 123	3.53	4.40	20	0.44	0.47	116	120	103	109	245	267	28	24	23.2	23.7
IR 83377-B-B-48-3	2.21	3.10	29	0.38	0.41	105	108	102	103	206	222	37	32	23.3	23.5
IR78937-B-3-B-B-1	2.08	3.27	36	0.36	0.42	112	115	101	104	204	217	42	33	22.6	22.8
BR7870-5*(NIL)-8-HR4	2.52	3.61	30	0.38	0.42	112	117	94	100	226	242	39	29	21.0	21.6
BR7873-5*(NIL)-51-HR6	3.04	4.01	24	0.42	0.44	102	105	99	102	252	267	28	25	20.7	21.0
NERICA 4	2.10	2.71	23	0.36	0.35	115	118	93	98	201	215	35	33	22.3	22.7
IR64 (Check)	2.38	3.50	32	0.41	0.44	107	110	88	91	219	240	37	28	22.2	22.5
Binadhan-7 (Ck)	2.60	4.16	38	0.40	0.46	112	115	91	97	249	265	41	26	22.8	23.3
BRRI dhan49 (Ck)	1.36	2.52	46	0.27	0.33	126	130	96	100	235	252	61	42	22.0	22.5
Guti Swarna (L. Ck)	1.30	3.01	57	0.25	0.36	134	136	103	109	240	258	62	41	22.6	23.0
$LSD_{0.05}$	0.33	0.24	-	0.03	0.02	1.2	1.5	1.3	1.0	9	7	4	3	0.6	0.5
F-test	***	***	-	***	***	***	***	***	***	***	***	***	***	***	***

***P≤0.001 (Strongly significant)

Table 6. Correlation coefficients among the traits of 30 genotypes under rainfed environment

Parameters	Grain yield (t ha^{-1})	Panicles m^{-2} (no.)	Sterility (%)	Grain wt. (g)	Plant ht (cm)	Biomass (t ha^{-1})	Harvest index
Wet season 2009							
Grain yield	1						
Panicles m^{-2}	0.661**	1					
Sterility (%)	-0.919**	-0.483**	1				
Grain weight	0.226*	-0.062 ns	-0.214ns	1			
Plant ht (cm)	0.206*	-0.025 ns	-0.151ns	0.310**	1		
Biomass	0.963**	0.707**	-0.831**	0.198ns	0.207ns	1	
Harvest index	0.919**	0.504**	-0.937**	0.231*	0.142ns	0.793**	1
Wet season 2010							
Grain yield	1						
Panicles m^{-2}	0.778**	1					
Sterility (%)	-0.928**	-0.689**	1				
Grain weight	0.175ns	-0.087ns	-0.059ns	1			
Plant ht (cm)	0.348**	0.160ns	-0.291**	0.312**	1		
Biomass	0.924**	0.840**	-0.854**	0.108ns	0.340**	1	
Harvest index	0.913**	0.572**	-0.851**	0.231*	0.317**	0.691**	1

*Significant at P≤0.05, **Significant at P≤0.01 and ns=not significant.

Across the experimental years and genotypes, plant height varied from 87 to 111 cm due to water stress. Panicle production m^{-2} ranged from 167 to 252 in 2009 while it was 190 to 267 during 2010WS. Moreover, the mega variety BRRI dhan49 and Guti Swarna produced significantly lower panicles m^{-2} than the highest one. The tested genotypes expressed high significant variability regarding spikelet sterility (Table 5). Sterility percentage was the highest (62%) in Guti Swarna during 2009WS despite the fact that the highest percentage of sterility (42%) was found in BRRI dhan49 and IR83376-B-B-24-2 in 2010WS. In contrast, IR74371-70-1-1 and IR83377-B-B-93-3 performed better with the lowest sterility 26 and 22%, respectively. Strong significant differences in respect of 1000-grain weight of the genotypes found in both the experimental years. Among the cultivars, IR83387-B-B-27-4 produced grain with highest 1000-grain weight (23.8 and 24.3 g in 2009 and 2010, respectively) at the same time as the genotype BR7873-5*(NIL)-51-HR6 gave constantly the lowest 1000-grain weight of 20.7 and 21.0 g in 2009 and 2010, respectively.

3.4 Relationship of grain yield and yield attributes

Correlation between yield and yield parameters was highly significant in both the experimental years (Table 6). Moreover, Fig.8 and 9 showed the relationship among grain yield with panicles m^{-2}, spikelet sterility, 1000-grain weight, plant height, biomass and harvest index during 2009 and 2010WS. The highest R^2 values (0.927 and 0.853 in 2009 and 2010Ws, respectively) found in the relation of yield and biomass followed by harvest index (Fig 7 and 8). Compound interrelationship among various traits was found between yield and yield components determining one depended variable such as grain yield. Grain yield showed positive association with all the parameters except spikelet sterility. Panicles m^{-2}, biomass and harvest index were high positively related with grain yield while plant height and 1000-grain weight low positively related. In contrast, spikelet sterility was high negatively related with grain yield during both the experimental years.

3.5 Root Biomass

Root biomass varied significantly across the genotypes in both experimental years. Most of the roots of all the genotypes existed in 0 to 10 cm soil depth and, thereafter reduced the root biomass into 10 to 40 cm depth. Among the 30 rice genotypes, the highest mean root dry matter (4.21 g/0.015 cm^3) was observed in the genotype IR74371-70-1-1 which was statistically similar to NERICA 4 (4.19 g/0.015 cm^3), IR83377-B-B-93-3 (4.15 g/0.015 cm^3), IRRI 123 (4.13 g/0.015 cm^3) and IR83381-B-B-6-1 (3.80 g/0.015 cm^3) across the two seasons. (Fig. 10). Root biomass ranged from 2.05 to 4.21 g/0.015 cm^3. Thereby, the five IR74371-70-1-1, NERICA, IR83377-B-B-93-3, IRRI 123 and IR83381-B-B-6-1 found drought tolerant.

4. Discussion

4.1 Drought stress quantifying based on rainfall, soil moisture and soil water potential

Different intensities of drought stress occurred in each season of the study, where drought severity was higher in 2009WS compared to 2010WS (Henry et al., 2011). Rainfall received by the crops of the experiments was considerably lower at the northwest region of Bangladesh (Karmakar et al., 2010). Moreover, the rains were very much unevenly distributed (Fig. 1) within the years and seasons (Haefele et al., 2006). Mean annual rainfall of the experimental years (744 and 897 mm in 2009 and 2010, respectively) were much lower than the country average 2300 mm ranged from 1000 to 5000 mm (Saleh et al., 2000; Karmakar et al., 2012).

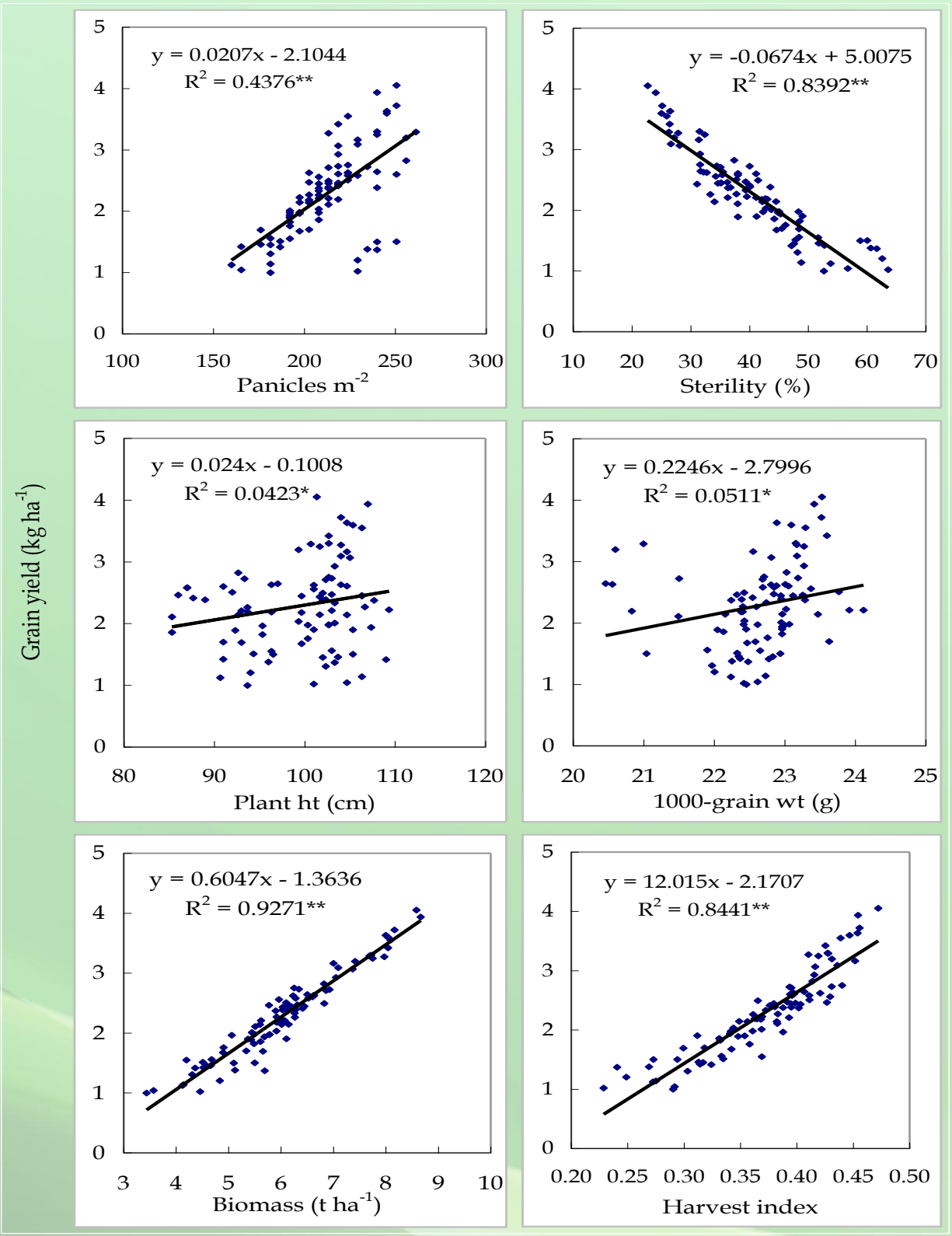


Figure 8. Relationship of grain yield and yield attributes of 30 rice genotypes under drought prone rainfed environment during 2009WS.

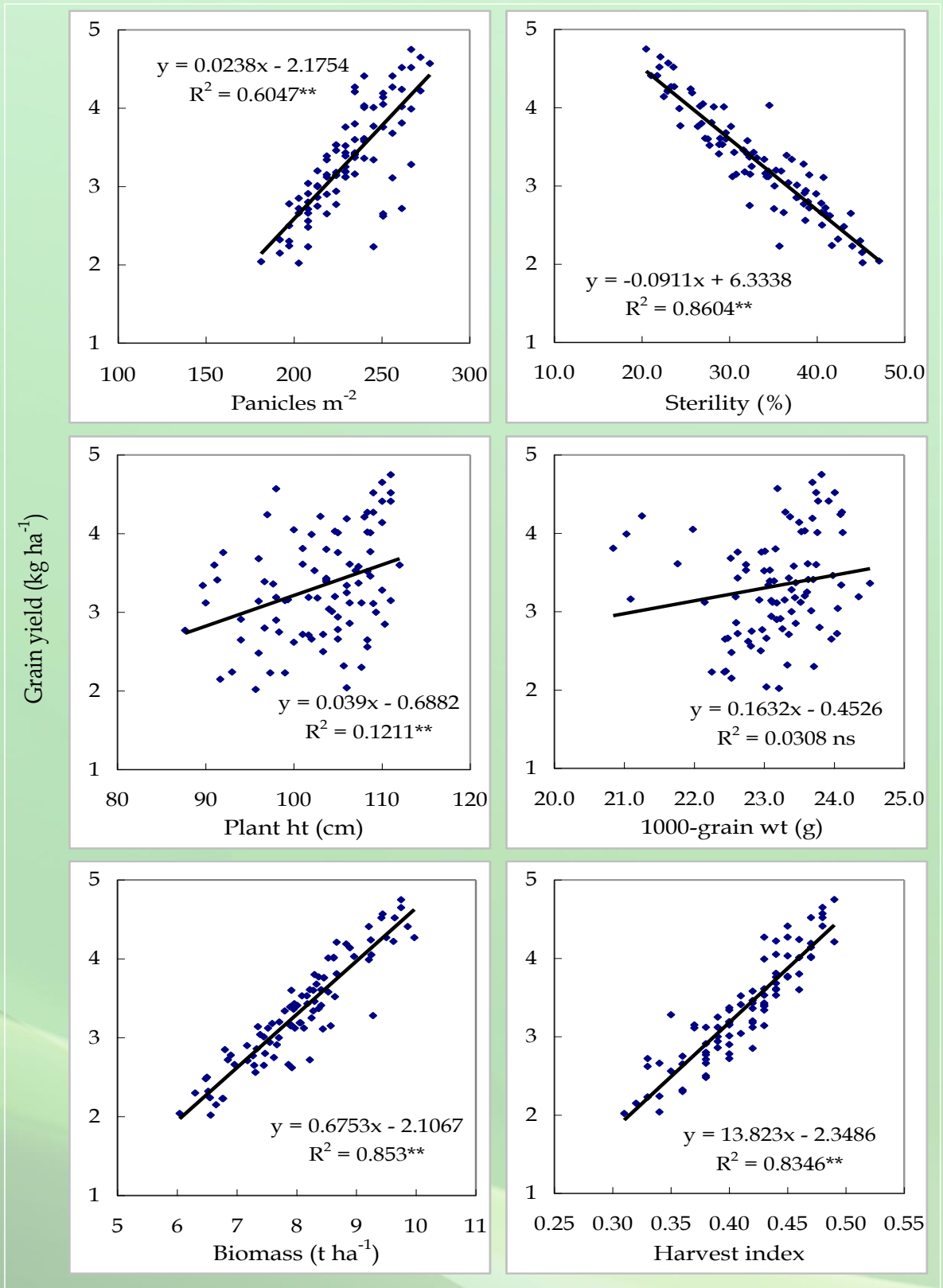


Figure 9. Relationship of grain yield and yield attributes of 30 rice genotypes under drought prone rainfed environment during 2010WS.

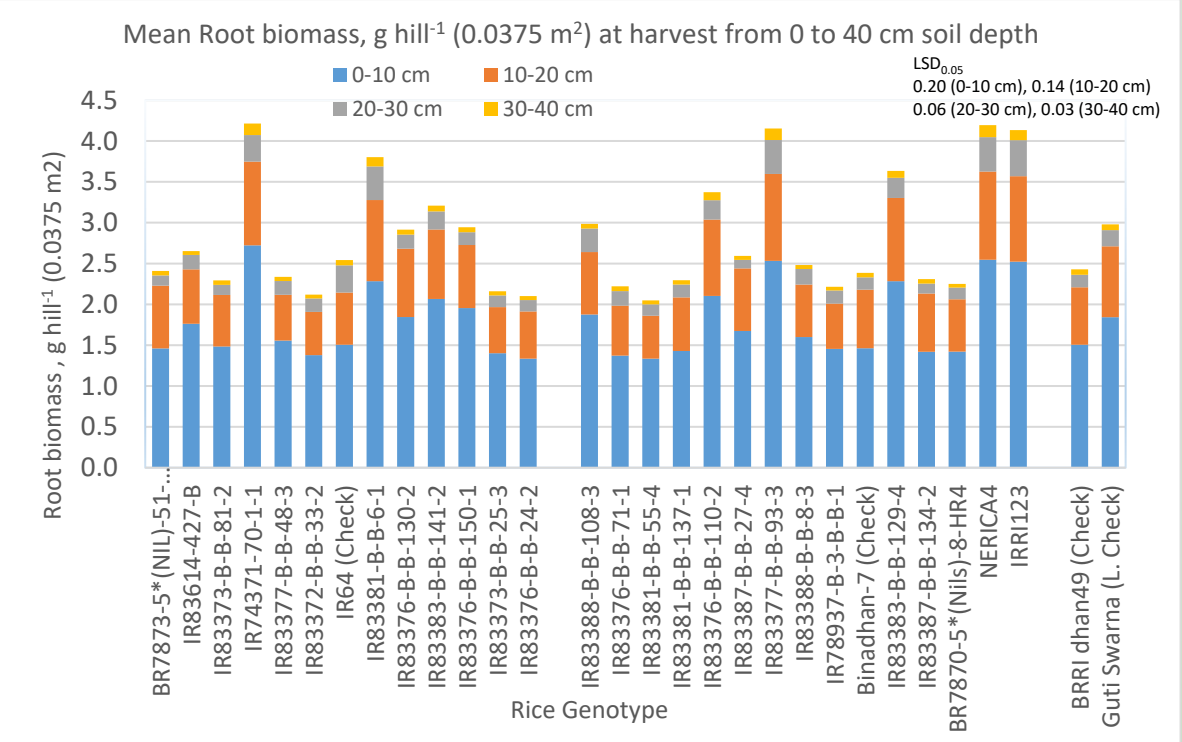


Figure 10. Mean Root biomass, g hill^{-1} (0.0375 m^2) of the rice genotypes in 0 to 40 cm soil depth at harvest under drought prone rainfed environment during 2009 and 2010WS

Meteorological data shows that much less rains occurred in 2009WS while 2010WS was moderately rainy (Fig. 1& 2). Consequently, the crop experienced substantial and intermittent drought stress in 2009 and 2010WS, respectively. Rainfall distribution, groundwater level (Haefele and Bouman, 2008) and soil moisture content and soil water tension (Henry et al., 2011) during reproductive phase of crop indicated a higher water stress for the trials conducted under rainfed environment. Consequently, no doubt that rainfall is an important determinant of the yield of rainfed lowland rice (Wade et al., 1998). Drought amount and duration varied in different crop stage as well as cropping years. Crop at vegetative stage did not face drought stress in both the years. However, severe drought stress existed in reproductive and ripening stage caused higher spikelet sterility (Islam and Islam, 2010) in 2009WS while it was moderate in 2010WS. Drought amount and duration was significantly higher in 2009WS than 2010WS that caused higher grain yield reduction (14 to 57%) in 2009WS over 2010WS. This result corroborates with Islam and Islam (2010) found that yield was reduced by 30 to 55% due to drought stress. Moreover, crop experienced severe drought stress with 43 drought days amounting 247 mm drought in 2009 while it was only 25 days and 107 mm in 2010, respectively. These findings are alignment with Islam et al. (2007) who reported maximum drought of 40 days and minimum drought of 22 days in northwest Bangladesh.

4.2 Genotype clustering through dendogram regarding phenotypic acceptability, leaf-rolling, leaf-drying and spikelet sterility

Dendogram of the rice genotypes showed drought stress severity that drawn based on phenotypic acceptability, leaf-rolling and leaf-drying score, and spikelet fertility. Genotypes belonging to the distant clusters maintained highest genetic variation. Genotypic variability in any crop is requirement for selection of superior genotypes over the existing cultivars (Murthy et al., 2011). The genotypes having lower inter cluster distances values in cluster I and III could be used as parents for the development of drought-resistant varieties. The other cluster (II) had the highest inter cluster mean value indicated that materials of this cluster are highly susceptible to drought. These results indicated, selection of genotype(s) from cluster III have positive impact and selection of genotype from cluster I and II have negative impact for drought resistant. It was preferential to make a decision that intra-cluster diversity was the highest in cluster I indicated more heterogeneous genotypes had in this cluster. Higher inter and intra cluster distances indicate higher genetic variability among genotypes between and within clusters, respectively. Phenotypic acceptability, leaf-rolling and leaf-drying at reproductive stage had positive impact in both the vectors. The characters that showed positive value in both vectors contributed most towards divergence. Spikelet sterility had negative impact in vector I and positive impact in vector II towards divergence. Double negative value of phenotypic acceptability at vegetative stage in vector I and II contributed lowest for divergence in the studied materials. Generally, positive value of the parameters like phenotypic acceptability, leaf rolling, leaf drying and spikelet sterility towards the vectors contributed higher for divergence while the negative value had lower contribution.

4.3 Genotypic variation on yield, yield attributes and agronomic parameters under drought stress

The tested genotypes varied significantly in respect of grain yield, yield attributes and agronomic parameters under drought stress (Murthy et al., 2011). It was might be due to the genotypic variability in response to drought stress of the genotypes (Sakai et al., 2010; Sarvestani et al., 2008). In general grain yield was lower in 2009WS compared to 2010WS as because drought stress was more in 2009WS than 2010WS. Genotypes responded differently under different drought stress conditions and habitually reduced grain yield of rainfed rice (Pantuwan et al., 2002b). Grain yield reduction varied from 14 to 57% due to drought stress across the cropping years and genotypes. Kumar et al., (2007) reported that drought stress at the flowering stage reduced yield by an average of 80% relative to a non-stressed control condition. Sarvestani et al. (2008) reported that grain yield reduced by 21, 50 and 21% due to water deficit at vegetative, flowering and grain filling stages, respectively. Yield of second year was higher than first year due to higher number of panicles m^{-2}, higher grain weight and lower spikelet sterility in 2010 compared to 2009. Genotypes performed differently in terms of yield and yield attributes under drought stress (Sakai et al., 2010). Long duration varieties like Guti Swarna and BRRI dhan49 suffered severely due to late season drought stress so that yield of these mega varieties reduced much more due to less panicle development and panicle exertion. Sarvestani et al. (2008) also found lower yield in the long duration cultivar Nemat due to late season drought. The low yield obtained in the genotypes was generally caused by a large percentage of unfilled grains per panicle due to reproductive phase drought (Wopereis et al., 1996). The main reasons for yield reduction was late season drought that were not suitable for panicle development impaired with reduced grain filling, grain number and weight (Sarvestani *et al.,* 2008; Islam et al., 1994; Bouman and Toung, 2001). Grain yield reduction resulted from greatly reduction of filled grain per panicle (Pantuwan et al., 2002a). Across the genotypes and years, harvest index fluctuated from 0.25 to 0.45 among the genotypes. These findings are in conformity with those of Fageria et al., 2010 and Kiniry et al., 2001. Harvest index varied significantly among cultivars ranging from 0.36 to 0.52 (Fageria et al., 2010) and from 0.35 to 0.62 (Kiniry et al., 2001) indicating the importance of this variable for yield stimulation. Harvest index generally was lower than the optimum level of high yielding variety in 2009 (more drought stress existed) but it was comparatively higher in 2010WS. Extremely low harvest index values related to drought stress resulted higher sterility, lower spikelet fertility, lower grain filling and lower grain weight and thereby grain yield (Haefele et al., 2003). Genotypes produced comparatively higher yield even under drought stress contained higher harvest index. These results are in accordance with Jearakongman et al. (1995) who reported that cultivars suitable for rainfed conditions are those with high yield potential resulting from high harvest index. Spikelet sterility and harvest index are the important parameters to quantify drought stress. Higher value of sterility and lower value of harvest index indicate susceptibility to drought tolerance (IRRI, 2002; Lafitte et al., 2002).

Days to flowering and maturity of almost all the genotypes in generally reduced by 1 to 5 days in 2009WS due to drought stress compared to 2010WS prevailed less drought stress. In general, time required to flowering ranged to a great extent among the genotypes and experimental years (Henry et al., 2012). Drought stress started from panicle initiation to maturity of many cultivars. However, some short duration genotypes escaped some extent this drought stress. Rainfed rice is extremely sensitive to water deficit from about 12 days before 50% flowering to about 7 days after flowering (Fischer et al., 2012). Drought stress at reproductive phase enhanced crop to reach early maturity. It happened might be due to water stress at reproductive stage forced the plant to switch over from flowering to maturity very faster. In contrast, many researchers (Sakai et al., 2008) reported that drought stress prior to flowering delayed flowering and maturity. However, Atlin et al., (2006) reported that days to flowering of high yielding rice varieties was delayed by 15 days while it was 5 days earlier for *japonica* varieties in water stressed drought prone environment than well watered condition. Plant height, panicles m^{-2}, grains $panicle^{-1}$, grain weight, fertility were reduced while sterility increased significantly in the severe drought year compared to less drought year. These findings are in agreement with Pantuwan *et al.,* (2002a) who reported that unfilled grain in the drought stress condition was 48% compared with 20% in well watered condition while 1000-grain weight was 18% smaller in drought stress. It happened might be due to genetically variability of the genotypes and also affected by drought stress (Fageria and Filho, 2007; Peng et al., 2000). Spikelet fertility was judged the most practical character by which to score cultivar performance (Garrity and O'Toole, 1994). It increased in comparatively less drought year 2010 over severe drought year 2009WS.

Grain yield was significantly and positively associated with all the yield attributes like panicles m^{-2}, grains $panicle^{-1}$, grain weight, spikelet fertility under drought stress however; spikelet sterility had negative correlation with yield (Pantuwan et al., 2002a; Murthy et al., 2011; Yadav, 1992). Haider *et al.,* (2012) also found that thousand grain weight (0.476**), grains per panicle (0.733**), spikelet fertility (0.709**) had positive and significant association with grain yield under drought stress; whereas, spikelet sterility had significantly negative correlation with yield. Short-duration genotypes would be preferable for many drought-prone environments because this could reduce the late-season drought risk and open options for post-rice crops in favorable years (Haefele et al., 2006). However, short duration variety has limitation that could produce comparatively lower yield than the mega variety in the

favorable years (Pantuwan et al., 2002a; Fischer et al., 2012). Drought resistant cultivars may be considered to be those produce higher grain yield under drought conditions (Pantuwan et al., 2002b).

4.4 Root biomass

Root biomass of the tested genotypes varied significantly across the genotypes (Fageria, 2010; Uddin et al., 2009). The highest root biomass (61.1%) of the genotypes located in the 0-10 cm soil depth followed by 10-20 cm (27.1%), 20-30 cm (8.8%) and the lowest (3.0%) was in 30-40 cm. These results are in alignment with the findings of Henry et al., 2011; Fageria, 2010; Uddin et al., 2009. That means most of the root system (88.2%) positioned to the top 20 cm of the soil layer. Similar findings also reported by Sharma et al. (1994) who found that 90% of the total root system restricted in the 0-20 cm soil depth. Some genotypes having more roots biomass extracted more water from deeper soil than others and acquired more drought tolerance.

5. Conclusion

Based on overall performances, the genotypes IR74371-70-1-1, NERICA4, IRRI 123, IR83377-B-B-93-3, and IR83381-B-B-6-1 were selected as drought tolerant and BR7873-5*(NIL)-51-HR6 was selected as drought escaping. From these findings, the genotypes IR74371-70-1-1 and BR7873-5*(NIL)-51-HR6 released as drought tolerant rice variety named BRRI dhan56 and BRRI dhan57, respectively through national variety release system. Rice cultivars having extensive deep root systems are proficient to mine moisture from deep soil layer indicated that more efficient in drought prone rainfed environments. Moreover, the selected genotypes could be utilized to improve varieties through classical breeding or using biotechnology linked with innovative agronomic management.

Declarations

Ethical Approval Certificate

The experimental procedures of this study were approved by the authority of Bangladesh Rice Research Institute, 1701, Gazipur, Bangladesh.

Author Contribution Statement

Biswajit Karmakar: Conceptualization, methodology, Research work execution, investigation and data collection; writing up original draft
Amelia Henry: Writing up original draft, Review and editing of the manuscript
Stephan M Haefele: Review and editing of the manuscript
Md. Habibur Rahman Mukul: Data compilation, curation validation and formal analysis
Mir Mehedi Hasan: Data compilation, curation validation and formal analysis
Arvind Kumar: Review and editing of the manuscript
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Abbreviations and Units:

AEZ: Agro-ecological Zone, AYT: Advanced yield trials, BRRI: International Rice Research Institute, DAT: date after transplanting, DT: Drought tolerant, DS: Drought susceptible, ET: Evapotranspiration, IRRI: International Rice Research Institute, OYT: Observational yield trial, PVC: Polyvinyl chloride, SMS: Soil moisture storage, SWS: Surface water storage, WS: Wet season.

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A Bibliometric Analysis on Food Waste and Sustainability in Central Asia

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Abstract

Food waste and sustainability have increasingly become the focus of the global agenda in regions facing economic, environmental, and food security problems. Central Asia, consisting of Kazakhstan, Kyrgyzstan, Uzbekistan, Turkmenistan, and Tajikistan, presents a unique context in this field due to its Soviet legacy, transitioning economies, and growing population. Food waste is not only a problem that causes economic losses, but also a global crisis that threatens environmental sustainability by leading to inefficient use of natural resources and an increase in greenhouse gas emissions. This waste, which occurs at all stages from agricultural production to consumption, is of great importance for the sustainability of food systems.

The aim of this study is to analyze scientific publications on food waste and sustainability in Central Asian countries (Kyrgyzstan, Kazakhstan, Uzbekistan, Tajikistan, Turkmenistan) using bibliometric methods, and to reveal regional research trends and academic collaboration structures. For this purpose, literature between 2000 and 2024 was scanned in Scopus and Web of Science databases using keywords such as “food waste,” “food loss,” “sustainability,” “Central Asia,” “Kyrgyzstan,” “Kazakhstan,” “Uzbekistan.” The obtained data were analyzed using the VOSviewer software.

According to the results, the number of publications on food waste and sustainability in Central Asia is limited, but has shown an increasing trend especially in the last five years. Academic collaborations with countries such as Türkiye, China, and Germany stand out. In the keyword analysis, concepts such as “climate change,” “agri-food systems,” “circular economy,” and “food security” came to the forefront. This study is important in terms of showing the research gaps and future academic opportunities for sustainable food systems in the region.

Key Words: *Central Asia, food waste, sustainability, bibliometric analysis, food security*

Orta Asya’da Gıda İsrafı ve Sürdürülebilirlik Üzerine Bibliyometrik Bir Analiz

Özet

Gıda israfı ve sürdürülebilirlik, ekonomik, çevresel ve gıda güvenliği sorunlarıyla karşı karşıya olan bölgelerde giderek artan bir şekilde küresel gündemin merkezine yerleşmiştir. Kazakistan, Kırgızistan, Özbekistan, Türkmenistan ve Tacikistan’dan oluşan Orta Asya, Sovyet geçmişi, geçiş sürecindeki ekonomileri ve artan nüfusu nedeniyle bu alanda benzersiz bir bağlam sunmaktadır. Gıda israfı, yalnızca ekonomik kayıplara yol açan bir sorun değil, aynı zamanda doğal kaynakların verimsiz kullanımına ve sera gazı emisyonlarının artmasına neden olarak çevresel sürdürülebilirliği tehdit eden küresel bir krizdir. Tarımsal üretimden tüketime kadar olan tüm aşamalarda meydana gelen bu israf, gıda sistemlerinin sürdürülebilirliği açısından büyük önem taşımaktadır.

Bu çalışmanın amacı, Orta Asya ülkelerinde (Kırgızistan, Kazakistan, Özbekistan, Tacikistan, Türkmenistan) gıda israfı ve sürdürülebilirlik konularında yapılmış bilimsel yayınları bibliyometrik yöntemle analiz ederek, bölgesel araştırma eğilimlerini ve akademik iş birliği yapılarını ortaya koymaktır. Bu kapsamda, 2000–2024 yılları arasındaki literatür, Scopus ve Web of Science veri tabanlarında “food waste”, “food loss”, “sustainability”, “Central Asia”, “Kyrgyzstan”, “Kazakhstan”, “Uzbekistan” gibi anahtar kelimeler kullanılarak taranmıştır. Elde edilen veriler VOSviewer yazılımı aracılığıyla analiz edilmiştir.

Analiz sonuçlarına göre, Orta Asya’da söz konusu konularda yapılan yayın sayısı sınırlı olmakla birlikte, özellikle son beş yılda artan bir eğilim göstermektedir. Türkiye, Çin ve Almanya gibi ülkelerle gerçekleştirilen akademik iş birlikleri dikkat çekmektedir. Anahtar kelime analizinde ise “climate change”, “agri-food systems”, “circular economy” ve “food security” kavramlarının öne çıktığı görülmüştür. Bu çalışma, bölgedeki sürdürülebilir gıda sistemlerine yönelik araştırma boşluklarını ve gelecekteki akademik fırsatları ortaya koyması açısından önemli bir kaynak niteliğindedir.

Anahtar Kelimeler: *Orta Asya, gıda israfı, sürdürülebilirlik, bibliyometrik analiz, gıda güvenliği*

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Assessment of Stress-Adaptative Traits in Durum Wheat (*T. turgidum subsp. durum*) Landraces Using Agromorphological, Physiological, and Proline Content Parameters

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Abstract
Drought is a significant challenge to wheat productivity in changing climate conditions. Breeding strategies have been successful in producing drought-resistant wheat varieties. This study aimed to assess the morpho-physiological and biochemical responses of durum wheat landraces to drought stress. Twenty landraces and four checks were grown in pots under non-stressed (70%) and stressed (35%) conditions, using a completely randomized design (CRD) with three replicates. Data on yield, yield-related traits, and physiological-biochemical characteristics were collected. ANOVA results indicated significant impacts of genotype and stress on all parameters, with drought having a noticeable influence on morpho-physiological and biochemical traits. Key characteristics for drought tolerance included earlier heading dates, optimal tiller production, and shorter grain filling periods. Maintaining high proline and relative water content (RWC) was crucial for supporting metabolic processes under stress. Phenotypic and genotypic correlations and path coefficient analysis offered insights into the direct and indirect effects of these traits on grain yield. Landraces ETDW/15DZ023, ETDW/15DZ04, 34217, and 31831 consistently produced high yields under non-stressed and stressed conditions, demonstrating superior drought tolerance compared to other tested genotypes. This highlights their potential for inclusion in breeding programs to improve drought resilience in durum wheat.

Key words: *Drought tolerance; Durum wheat; Greenhouse; Physiological trait; Proline content; Stress-adaptative*

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Enhancing Cotton Yield through Adoption of Climate Smart Agriculture: A Case of Smallholder Farmers in Bariadi District, Tanzania

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Abstract

Climate variability threatens cotton farming in Tanzania, highlighting the need for sustainable strategies to boost smallholder productivity and resilience. This study aimed to establish the effects of Climate Smart Agriculture (CSA) practices on cotton yield among smallholder farmers in Bariadi District, Simiyu Region, Tanzania. Specifically, the study sought to determine the effects of CSA practices on cotton yield among cotton smallholder farmers. A cross-sectional research design was employed, and data were collected using structured questionnaires from a sample of 384 smallholder cotton farmers. Descriptive analysis revealed varied levels of CSA adoption, with intercropping, soil and water conservation, and integrated pest management being among the most practiced. The Ordinary Least Squares (OLS) regression analysis was used to estimate the effects of CSA practices and selected socio-economic factors on cotton yield. The results showed that adoption of intercropping, integrated pest management, soil and water conservation techniques, efficient irrigation methods, and access to CSA-related training had statistically significant positive effects on cotton yield. Moreover, farm size and having alternative sources of income particularly government employment and commercial work were also positively associated with increased cotton production. The study concludes that CSA practices significantly contribute to higher cotton yield and potentially enhance household income. Therefore, it is recommended that local government authorities and Ministry of Agriculture strengthen agricultural extension services and prioritize regular on-farm training and demonstration programs to improve farmers' awareness and practical adoption of CSA practices.

Keywords: *Climate Smart Agriculture, cotton yield, smallholder farmer*

ID: 671

Enhancing Cotton Productivity through Adoption of Climate Smart Agriculture: A Case Study of Smallholder Farmers in Bariadi District, Tanzania

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Abstract

Climate variability threatens cotton farming in Tanzania, highlighting the need for sustainable strategies to boost smallholder productivity and resilience. This study aimed to establish the effects of Climate Smart Agriculture (CSA) practices on cotton yield among smallholder farmers in Bariadi District, Simiyu Region, Tanzania. A cross-sectional research design was employed, and data were collected using structured questionnaires from a sample of 384 smallholder cotton farmers. Descriptive analysis revealed varied levels of CSA adoption, with diversified crop planting, intercropping, soil and water conservation, and integrated pest management being among the most practiced. The Ordinary Least Squares (OLS) regression analysis was used to estimate the effects of CSA practices and selected socio-economic factors on cotton yield. The results showed that adoption of intercropping, integrated pest management, soil and water conservation techniques, irrigating with motor powered pump, and access to CSA related training had statistically significant positive effects on cotton yield. Moreover, farm size and having alternative sources of income particularly government employment and commercial work were also positively associated with increased cotton production. The study concludes that CSA practices significantly contribute to higher cotton yield and potentially enhance household income. Therefore, it is recommended that local government authorities and Ministry of Agriculture strengthen agricultural extension services and prioritize regular on-farm training and demonstration programs to improve farmers' awareness and practical adoption of CSA practices.

Background information

Agriculture is the backbone of livelihoods across Sub-Saharan Africa (Nyathi et al., 2025; AGRA, 2022) employing nearly two-thirds of the population. In many Sub-Saharan African countries, agriculture contributes approximately 30% to the region's GDP (Hodjo et al., 2023). Smallholder farmers cultivate many crops including cotton for business purpose. However, the sector faces growing threats from climate change, including erratic rainfall patterns, prolonged droughts, soil degradation, and increasing pest infestations (FAO, 2023; Alotaibi et al., 2023; Ruiz & McCue, 2024). These challenges have led to declining agricultural productivity (Ruiz and McCue, 2024; Cunningham et al., 2021) particularly among smallholder farmers who lack access to modern technologies and they have opted for climate change adaptation strategies to secure cotton yield (Fadeyi, et al., 2022).

In Eastern Africa, agriculture is equally vulnerable, with climate change projected to reduce crop yields by up to 30% by 2050 if no adaptive measures are taken (World Bank, 2022). Cotton, an important cash crop in many parts of the region, has been particularly affected due to its sensitivity to water stress, pest , disease infestations and low yield (Malinga & Laing, 2023; Babu et al., 2024; Faisal et al., 2025; Tlatlaa et al., 2023). In countries like Ethiopia, Mali, Kenya, South Africa and Tanzania, cotton farming is largely dominated by smallholder farmers with limited capacity to respond to climate risks (Salisali, 2016; Bwana *et al.,* 2020).

In Tanzania, cotton is the second-largest export crop after tobacco and supports over 500,000 smallholder farmers, primarily in the Western Cotton Growing Area (WCGA), which includes Simiyu Region and Bariadi District in particular (Tanzania Cotton Board, 2023). Despite its economic importance, cotton yields remain low and unstable due to climate-related constraints and poor farming practices and volatile market (Cornelia & Bernhard, 2015). Smallholder farmers in Tanzania including those in Bariadi District continue to rely on rain-fed systems, outdated agronomic techniques, and lack access to extension services or climate-resilient innovations (Abdallah, 2020; Yao, 2023).

To address these challenges, Climate Smart Agriculture (CSA) has been promoted as a sustainable solution to boost crop productivity while enhancing resilience to climate shocks (AkhRegmi & Paudel, 2024; Tilahun et al., 2025; Ma & Rahut, 2024). CSA is an integrated approach that involves the adoption of techniques such as intercropping, conservation agriculture, efficient irrigation, integrated pest management (IPM), and access to weather and agronomic information (Lipper et al., 2014). While numerous studies including (Bongole, 2023; Jones et al., 2023; Yusuph et al., 2024; Msongaleli, 2024;Erick et al., 2025) have shown the benefits of CSA in improving yields for staple crops like maize, leaf vegetables and rice in Tanzania, less is known about its

effectiveness in cotton production. In the Bariadi District, climate variability particularly unreliable rainfall and prolonged dry spells has increasingly threatened cotton productivity. While some farmers have begun adopting CSA practices, the uptake remains uneven and poorly documented. There is a critical knowledge gap regarding which specific CSA practices are most effective in enhancing cotton yield under local conditions, and what socio-economic factors influence their adoption. Therefore, this study was undertaken to examine the effects of CSA practices on cotton yield among smallholder farmers in Bariadi District. By identifying the most impactful practices and associated socio-economic drivers, the study aims to provide evidence-based insights to guide agricultural policy, extension services, and investment in climate-resilient cotton farming systems.

Theoretical underpinnings

This study is anchored in Rogers' (2003) Diffusion of Innovation Theory**,** which explains how new ideas and technologies spread within a social system. According to this framework, the diffusion process is shaped by three core elements: the traits of the individuals adopting the innovation, the attributes of the innovation itself, and the communication pathways through which the innovation is conveyed. In the context of this research, household characteristics such as gender, education level, marital status, age, income sources, farm size, and farming experience correspond to the adopter traits highlighted in the theory. The innovation attributes namely, Climate Smart Agriculture (CSA) practices including diversified cropping, intercropping, soil and water conservation, integrated pest management, and irrigation using motorized pumps align with the theory's emphasis on the perceived features of innovations. Furthermore, the institutional mechanisms that influence dissemination, such as access to agricultural training, credit facilities, and farm inputs, represent the communication channels that facilitate the diffusion process within cotton smallholder farmers in the study area.

Methodology

Study Area

The study was conducted in Bariadi District at Sapiwi and Dutwa wards. The study area was selected because it is characterized by its semi-arid climate, with erratic rainfall patterns and high temperatures posing challenges to agricultural production, particularly cotton (Malamsha & Lughuyu, 2024). In addition, the study areas were selected because the primary economic activity is agriculture, with cotton farming being a key sector (URT, 2017).

Research design, sampling procedure and sample size

The study used a cross-sectional research design, with all cotton smallholder farmers in the study area serving as the sampling frame. The sampling unit was the individual cotton smallholder farmer, and a multistage sampling method was used to select respondents. First, Bariadi District was purposively selected, followed by Sapiwi and Dutwa wards, where cotton farming is the main economic activity. Next, five villages were purposively chosen three from Sapiwi and two from Dutwa. Finally, cotton smallholder farmers were selected through simple random sampling.

The total population of 9,717 cotton smallholder farmers was used to calculate the sample size of 384 farmers, applying Yamane's formula as follows:

$$n = \frac{N}{1+N\,(e)^2} = \frac{9717}{1+9717(0.05)^2} = 384 \quad \text{..... (i)}$$

In this formula, n represents the sample size, N is the total population (9,717 cotton farmers), and e is the margin of error or precision level (set at 5 percent). According to Bariadi Agricultural Marketing Cooperative Society (AMCOS), the village populations were as follows: Igegu (2,850), Sapiwi (1,800), Nyamikoma (1,567) from Sapiwi ward, and Itemelo (1,800) and Ipundula (1,700) from Dutwa ward.

The sample size for each village was then calculated using Salkind's (2010) proportional sampling formula, as shown in equation (ii) and Table 1:

$$n_b = \frac{N_h}{N} \text{ x } n \quad \text{.....(ii)}$$

Here, n_b is the sample for each village, N_h is the population of the village, N is the total population across all five villages, and n is the total sample size of 384 farmers. For example, the sample for Igegu was calculated as follows: $n_b = (2{,}850 / 9{,}717) \times 384 \approx 113$.

Table 1: Sample size composition of the villages in the study area

Ward	Village	Population	Sample size
Sapiwi	Igegu	2850	113
	Sapiwi	1800	71
	Nyamikoma	1567	62
Dutwa	Itemelo	1800	71
	Ipundula	1700	67
	Total	9717	384

Data collection methods

Information was obtained from both primary and secondary sources to enhance the accuracy and depth of the findings. Primary data were gathered through a household survey using semi-structured questionnaires administered to cotton smallholder farmers affiliated with cooperatives (AMCOS) in Sapiwi and Dutwa wards. Secondary data were obtained by reviewing agricultural policies, scholarly literature, books, articles, and other relevant documents to provide background and supporting insights for the study.

Measurement of the study variables

In the study area, cotton smallholder farmers were interviewed to examine how Climate Smart Agriculture (CSA) practices influence cotton yield. Based on their farming experience, farmers reported adopting several CSA practices, including crop diversification, intercropping, soil and water conservation, irrigation using motor-powered pumps, and integrated pest management (Bongole, 2023; Erick et al., 2025; Sekabira et al., 2022). In this study, these CSA practices were treated as independent variables. Additional independent variables, along with the dependent variable cotton yield are outlined in Table 2, which provides descriptions and measurement details for each variable used in the analysis.

Table 3.7.1: List of variables and their measurement scales

Variable	Scale	Measurement
Cotton growers yield	Ratio	Kilograms per hector
Age of a Cotton grower	Ratio	Years
Years of practicing CSA Practices (experience)	Ratio	Years
Farm size	Ratio	Hectors
Education	Ordinal	Informal education, primary education, Secondary education or tertiary education
Marital Status	Nominal	Single, married, widowed and divorced
Other Source of Income besides farming	Nominal	Peasant, Agri-non farm entrepreneur, government employee and other sources of income
CSA practices implemented by a cotton grower	Nominal	Diversified crop planting, Intercropping, Soil and water conservation technique, Integrated pest management and irrigating with motor powered pump
Access to funds for adoption of CSA	Nominal	Yes and No
Access to information and training	Nominal	Yes and No
Access to agricultural inputs	Nominal	Yes and No

Data analysis

The quantitative data were analyzed by using SPSS version 20 and Stata version 16. SPSS was used to analyze descriptive statistics of the socio-economic, technological and institutional factors of the surveyed households. In the case of inferential statistics, the quantitative data were coded and entered in the stata version 20 for analysis. The inferential statistics applied Ordinary Least Squares (OLS) regression to analyze the influence of climate smart agriculture practices on cotton yield among smallholder farmers in the study area.

Estimation of the model

The Ordinary Least Squares (OLS) regression model was employed in this study to assess the effect of Climate Smart Agriculture (CSA) practices on cotton yield among smallholder farmers. OLS is suitable because the dependent variable cotton yield is continuous and measurable in quantitative units (e.g., kilograms per hectare). This method allows for estimating the linear relationship between multiple independent variables (adopted CSA practices and other socioeconomic factors) and the outcome variable cotton yield. Moreover, OLS is widely used in agricultural economics due to its simplicity, interpretability, and ability to provide unbiased and efficient estimates under the assumption of linearity, homoscedasticity, and normally distributed residuals (Mahaboob et al., 2018; Fox, 2016).

The Ordinary Least Squares (OLS) regression model (equation iii) was applied as follows;

$$Y = \beta_0 + \beta_i X_i + \beta_i D_{kj} + \varepsilon_i$$

Where Y is the dependent variable (Yield), β_0 is the intercept of the model, β_i is the coefficients of the explanatory variables to be estimated, X_i corresponds to the i^{th} continuous explanatory variable of the model ($i = 1\ to\ 4$), D_{kj} corresponds to the i^{th} categorical/dummy explanatory variable of the model ($k = 1\ to\ 11$) and ε is the random error with expectation 0 and variance σ^2.

Results

Socio-economic characteristics of the respondents

Table 2 presents the socio-economic characteristics of cotton smallholder farmers in the study area. A total of 384 respondents participated, with 41.4% from Dutwa Ward and 58.6% from Sapiwi Ward. The sample was predominantly male (69.5%), while females accounted for 30.5%.In terms of education, most farmers had attained primary education (56%), followed by secondary education (27.3%), informal education (11.5%), and tertiary education (5.2%). Regarding marital status, the majority were married (63.8%), while 22.7% were single, 13% were widowed, and only 0.5% were divorced. In terms of other sources of income besides farming, the vast majority identified as peasants (78.4%), followed by Agri-non farm entrepreneur s (17.7%), government employees (3.7%), and a small fraction (0.3%) under other categories.

Table 2: Socio-economic characteristics of the respondents

Variable	Frequency	Percent
Ward		
Dutwa ward	159	41.41
Sapiwi ward	225	58.59
Sex		
Male	267	69.53
Female	117	30.47
Education		
Informal education	44	11.46
Primary education	215	55.99
Secondary education	105	27.34
Tertiary education	20	5.21
Marital Status		
Single	87	22.66
Married	245	63.8
Widow	50	13.02
Divorced	2	0.52
Other Sources of Income besides farming		
Peasant	301	78.39
Agri-non farm entrepreneur	68	17.71
Government employee	14	3.65
Other	1	0.26

Climate-Smart Agriculture Practices and Socio-Economic Characteristics

Table 3 summarises the climate-smart agriculture (CSA) practices adopted by cotton farmers along with other key socio-economic characteristics. Among the 384 farmers surveyed, nearly half (49.5%) practiced diversified crop planting, while 41.4% used intercropping methods. Soil and water conservation techniques were applied by 7.6% of the farmers, irrigating with motor powered pump (1.0%) and very few adopted integrated pest management (0.5%).

Regarding access to resources, only 10.7% of the farmers reported having access to credits to support CSA adoption, while a striking 89.3% did not (Table 3). Extension services played an important role, with 83.1% of farmers confirming they received support from extension officers promoting CSA practices. Access to information and training was reported by 86.2% of farmers, showing a strong flow of knowledge within the farming community. Finally, 59.6% of cotton farmers had access to agricultural inputs, whereas 40.4% lacked such access (Table 3).

Ordinary Least Squares (OLS) regression results

An Ordinary Least Squares (OLS) regression was conducted to estimate the effects of Climate Smart Agriculture (CSA) practices and socio-economic factors on cotton yield among smallholder cotton farmers in Bariadi District. The model showed a good fit with an **R-squared of 0.2537** and an **adjusted R-squared of 0.2126**, indicating that about 21% of the variation in cotton yield is explained by the predictors in the model.

Significant Factors Affecting Cotton Yield

Farm size

Study findings showed that farm size was positively and significantly related to cotton yield, with a regression coefficient (β) of 64.02 and a p-value below 0.01. This means that as the size of a farmer's land increases, their cotton yield also tends to increase. Specifically, for every additional unit of land (hectare), the cotton yield is expected to rise by approximately 64.02 units, assuming all other factors remain constant. The small p-value ($p < 0.01$) indicates that this relationship is statistically significant, meaning there is strong evidence that farm size is an important factor influencing cotton yield in the study area.

Table 3: Climate smart agriculture practices adopted by farmers and other socio-economic characteristics

CSA practices and socio-economic factors	Frequency	Percentage
Diversified crop planting	190	49.48
Intercropping	159	41.41
Soil and water conservation technique	29	7.55
Integrated pest management	2	0.52
Irrigating with motor powered pump	4	1.04
Access to credits		
Yes	41	10.68
No	343	89.32
Access to extension services		
Yes	319	83.07
No	65	16.93
Access to information and training		
Yes	331	86.2
No	53	13.8
Cotton Grower has access to Agricultural Inputs		
Yes	229	59.64
No	155	40.36

Table 4: OLS Regression of Climate Smart Agriculture Effects on Cotton Yield

Dependent Variable: Cotton Yield	Coefficient	Std. Err.	P>t
Age	-1.6562	1.7345	0.340
Years of practicing CSA	27.0292	17.9499	0.133
Farm Size in Ha	64.0187***	15.1958	0.000
Level of education			
Informal education	60.6510	57.2088	0.290
Secondary education	-39.5652	42.4701	0.352
Tertiary education	-36.6537	80.7915	0.650
Marital status			
Single	1.8644	43.7970	0.966
Widow	68.6095	55.1393	0.214
Divorced	-125.8892	232.4816	0.588
Other Source of Income Besides Farming			
Agri-non farm entrepreneur	114.1314**	46.6475	0.015
Government employee	281.4357***	97.2645	0.004
Other	-435.0019	317.9133	0.172
Diversified Crop Planting			
No	28.9294	42.8105	0.500
Intercropping			
No	-90.5841**	39.0213	0.021
Soil and Water Conservation Technique			
No	-130.8486***	39.3812	0.001
Integrated Pest Management			
No	-185.4597***	48.1778	0.000
Irrigating with motor powered pump			
No	-124.5501**	55.2460	0.025
Accessed credit for Adoption of CSA Practices			
No	-20.2551	53.7549	0.707
Access to information and training			
No	-203.7884***	54.5326	0.000
Access to agricultural inputs			
No	10.1291	35.6809	0.777
Constant	1131.2670***	113.6792	0.000

R-squared =0.2537; Adj R-squared=0.2126, significance levels of 1%, 5%, and 10% are indicated by ***, **, and * respectively.

Other sources of income such as government employee

The findings revealed that government employment was strongly and significantly linked to higher cotton yields, with a regression coefficient (β) of 281.44 and a p-value less than 0.01. On average, government employees produced approximately 281.44 more units of cotton compared to farmers in other occupational groups, holding all other variables constant. The low p-value ($p < 0.01$) confirms that this difference is statistically significant, providing strong evidence that government employees consistently achieved higher yields than their counterparts in the study.

Agri-non-farm entrepreneur

The study results indicated that being a Agri-non-farm entrepreneur was significantly associated with higher cotton yields, with a regression coefficient (β) of 114.13 and a p-value below 0.05. This means that, on average, Agri-non-farm entrepreneur s produced about 114.13 units more cotton compared to farmers from other occupational groups, assuming all other factors remain constant. The p-value ($p < 0.05$) indicates that this difference is statistically significant, meaning there is solid evidence that Agri-non-farm entrepreneur s achieved higher yields compared to others in the study.

Intercropping

The results showed that intercropping had a significant positive effect on cotton yields. Specifically, when farmers did not practice intercropping, their yields were about 90.58 kg/ha lower ($\beta = -90.58$, $p < 0.05$), compared to those who did intercrop, assuming all other factors remained constant. The negative coefficient means that the absence of intercropping reduced yields, highlighting the important role of intercropping in boosting cotton productivity. The p-value ($p < 0.05$) confirms that this result is statistically significant, providing strong evidence that intercropping contributes to higher cotton yields.

Soil and water conservation technique

The results indicates that soil and water conservation techniques had a strong positive effect on cotton yields. When farmers did not apply these practices, their yields were reduced by about 130.85 kg/ha ($\beta = -130.85$, $p < 0.01$), compared to farmers who used them, assuming all other factors remained constant. The negative coefficient indicates that the absence of these techniques significantly lowered yields, underlining the important role they play in improving cotton productivity. The p-value ($p < 0.01$) shows that this result is statistically significant, providing strong evidence that adopting soil and water conservation practices leads to better yields.

Integrated pest management (IPM)

The study findings revealed that integrated pest management (IPM) had the most substantial positive impact on cotton yield among the factors examined. Specifically, the yield decreased by 185.46 kg/ha when IPM was not applied ($\beta = -185.46$, $p < 0.01$), showing a highly significant relationship. This means that farmers who implemented IPM practices achieved notably higher cotton yields compared to those who did not. The strong effect can be attributed to IPM's ability to effectively control pest populations, reduce crop damage, and improve overall plant health, ultimately enhancing productivity.

Irrigating with motor powered pump

The results showed that irrigating with motor-powered pump had a significant positive effect on cotton yield. When motor-powered pumps were not used for irrigation, the yield declined by 124.55 kg/ha ($\beta = -124.55$, $p < 0.05$), indicating a meaningful relationship. This suggests that farmers who irrigated with motor-powered pumps achieved notably higher yields compared to those relying on less efficient or traditional methods. The positive impact is likely due to the ability of motor-powered pumps to provide a steady and sufficient water supply, reduce water stress, and improve nutrient uptake, all of which contribute to better crop growth and higher cotton yield.

Access to Climate Smart Agriculture practices related training and information

The analysis revealed that access to CSA-related training and information had a significant positive impact on cotton yield. Farmers who did not have access to such training and information experienced a yield decrease of 203.79 kg/ha ($\beta = -203.79$, $p < 0.01$), indicating a highly significant relationship. This finding suggests that farmers who received training and information on climate-smart practices achieved considerably higher yields compared to those who lacked such support. The positive effect is likely because training equips farmers with knowledge on best practices, efficient resource use, and adaptive strategies, all of which help improve cotton yield and resilience to climate related challenges.

Discussion

The socio-economic profile of cotton farmers in Bariadi District highlights important structural factors shaping agricultural practices and livelihood outcomes. The predominance of male farmers and those with primary-level education aligns with patterns reported in other Tanzanian farming communities, where limited education often constrains technology adoption and farm productivity (Mmbando & Baiyegunhi, 2016). The dominance of married households suggests the importance of family labor in cotton production, consistent with findings by Chami (2018).

In addition, the uptake of climate-smart agriculture (CSA) practices among cotton farmers is shaped by both technical and socio-economic factors. Consistent with Ma and Rahut (2024) and Ewulo et al. (2025) access to extension services and training plays a crucial role in improving farmers' knowledge and willingness to adopt CSA innovations. However, limited access to credit remains a key barrier, as echoed in Agyekum et al. (2024), who emphasized that financial support is essential to scale CSA practices effectively.

The adoption of Climate-Smart Agriculture (CSA) practices has been shown to significantly enhance cotton yields among smallholder farmers in Bariadi District. Our analysis identified several key CSA practices including intercropping, soil and water conservation techniques, integrated pest management (IPM), and irrigating with motor powered pump that positively influence cotton yield.

Intercropping emerged as a highly beneficial practice, with farmers who adopted it achieving significantly higher yields compared to those using monoculture systems. This finding is consistent with recent evidence showing that intercropping optimizes resource use efficiency by improving light interception, nutrient uptake, and soil moisture utilization (Ma & Rahut, 2024). Beyond immediate productivity gains, intercropping also enhances soil fertility through complementary plant interactions, contributing to long-term system sustainability and resilience against environmental stresses.

The adoption of soil and water conservation techniques emerged as a significant factor in enhancing cotton yields, underscoring their role in maintaining soil fertility and optimizing moisture availability. These practices not only reduce soil erosion but also strengthen the soil's capacity to retain water, which is essential for stabilizing yields under increasingly erratic rainfall patterns linked to climate change (Li et al., 2023). Moreover, their integration into farming systems contributes to long-term sustainability by improving soil structure, enhancing nutrient cycling, and reducing vulnerability to land degradation.

Integrated Pest Management (IPM) demonstrated the strongest positive impact on cotton yield, highlighting its critical role in sustainable crop production systems. By combining biological, cultural, and mechanical control methods, IPM not only reduces dependence on chemical pesticides but also fosters ecological balance within the agroecosystem (Zhou et al., 2023). This holistic approach enhances pest suppression, minimizes crop damage, and improves overall plant health, ultimately translating into higher and more stable yields. Moreover, IPM's emphasis on environmental stewardship positions it as a cornerstone strategy for resilient and climate-smart cotton farming.

The use of motor-powered pumps for irrigation emerged as a key driver of cotton productivity, with farmers utilizing this technology attaining significantly higher yields. This underscores the pivotal role of efficient and reliable water management in optimizing cotton production, particularly in regions prone to rainfall variability. Consistent with recent research, motorized irrigation not only improves water use efficiency but also enables timely water delivery during critical growth stages, thereby safeguarding yields under water-limited conditions (Kifle et al., 2022). Furthermore, its adoption reflects the increasing importance of mechanization in enhancing smallholder resilience and productivity.

Furthermore, access to CSA related training and information was positively correlated with higher cotton yields. This highlights the role of agricultural extension services in facilitating the adoption of improved practices. Recent research emphasizes that informed farmers are more likely to implement CSA techniques effectively, leading to better outcomes (Asante et al., 2024).

Conclusion

The study concludes that the adoption of Climate Smart Agriculture practices is not just beneficial it is essential for improving cotton yield and building resilience among smallholder farmers in the face of climate variability. However, for these benefits to be fully realized, farmers must be supported with targeted interventions such as access to training, irrigation technologies, and off-farm income opportunities. The results highlight the importance of practical, context-specific support systems that enable farmers to adopt and sustain CSA practices.

In conclusion, promoting CSA adoption among cotton farmers in Bariadi District is a viable pathway toward sustainable agricultural productivity, improved livelihoods, and long-term climate resilience. Policymakers, extension agents, and development partners should prioritize actions that break down barriers to CSA implementation and ensure that no farmer is left behind in the transition toward climate-smart cotton production.

Recommendations

Based on the findings of this study, several practical and actionable recommendations are proposed to enhance cotton yields among smallholder farmers in Bariadi District through increased adoption of Climate Smart Agriculture (CSA) practices.

Firstly, the Ministry of Agriculture, in collaboration with local government authorities and NGOs, should strengthen access to CSA training and extension services. This can be done by recruiting and deploying more extension officers who are well-trained in CSA practices. These officers should conduct regular on-farm training, set up demonstration plots, and utilize mobile platforms to deliver advisory services in local languages. This

approach ensures that even farmers with limited formal education can understand and implement practices such as intercropping, efficient irrigation, soil conservation, and integrated pest management.

Secondly, the District Agricultural Office should partner with the National Irrigation Commission and agro-tech companies to scale up the availability of efficient irrigation technologies. This can involve providing subsidized drip or sprinkler irrigation kits to farmers, especially those in drought-prone areas. Establishing Water User Associations (WUAs) will help farmers manage shared irrigation infrastructure and ensure sustainability through local oversight and maintenance.

Thirdly, local governments and farmer cooperative unions should facilitate improved access to agricultural inputs by organizing farmers into cooperatives. These cooperatives can engage in bulk purchasing of key inputs such as pest control products, irrigation equipment, and improved cotton seed varieties. Additionally, cooperatives can serve as platforms for technical training and sharing of best practices among members.

Another critical recommendation is to promote off-farm income opportunities to enable farmers to invest in CSA technologies. District Development Officers, in partnership with the Ministry of Labor and Employment, vocational training centers, and private sector actors, should implement rural employment schemes and small business initiatives. Programs could include agro-processing, community infrastructure development, and vocational skills training. These alternative income sources can reduce financial barriers that limit CSA adoption.

Furthermore, village agricultural committees, supported by the Tanzania Agricultural Research Institute (TARI), should lead community-based land management programs that promote intercropping and soil conservation. This could involve distributing starter seed packs for legume intercrops and training lead farmers in techniques like contour farming and mulching, which help preserve soil structure and moisture.

Finally, Ward Agricultural Officers should work with local farmer groups to establish CSA champions at the village level. These are lead farmers who will model best practices, host demonstration activities, and provide peer guidance. To keep them motivated and impactful, they should receive technical support, inputs, and community recognition.

In sum, these recommendations call for coordinated action from government agencies, research institutions, NGOs, and local community structures to drive adoption of CSA practices and enhance cotton productivity in a sustainable, inclusive manner.

Declarations

Author Contribution Statement

Fredrick Alleni Mfinanga: Data collection, supervision and wrote the original manuscript.

Barikiel Israel Panga: Analysed data.

Jacqueline Temba: Literature review, results presentation, discussion, article formatting, proofreading and editing.

Conflict of Interest

Authors declare no conflict of interest.

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Fish farmers' choice of adaptation strategies to climate change in Bayelsa State

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Abstract

This study examines the choice of climate change adaptation strategies among fish farmers in Bayelsa State. The specific objectives were to describe the socio-economic characteristics of the fish farmers and to examine the effect of socioeconomic characteristics of the farmers on their choice of climate change adaptation strategies in the study area. The study selected 120 fish farmers using multistage random sampling methods and primary data were collected from the farmers using questionnaire. The study employed frequency, percentages, mean, and multinomial logistic regression model to analyze data. The results indicate that household income, educational status, and access to credit are the most significant determinants of farmers' adaptation choices. Older farmers tend to adopt more adaptation strategies due to their experience, while larger household sizes positively influence labor-intensive adaptation techniques. Educational status strongly impacts information and education strategies, as well-educated farmers are more likely to access and utilize climate-related information. Farm size and extension contact significantly affect economic and diversification strategies, highlighting the importance of resource availability and advisory services in adaptation efforts. The study recommends the implementation of targeted policies to support farmers in building climate resilience. These include enhancing access to credit through financial programs, strengthening agricultural extension services, and promoting education on climate adaptation practices. Furthermore, investing in climate-resilient infrastructure and providing incentives for sustainable farming practices can improve farmers' adaptive capacity. By addressing these socioeconomic barriers, policymakers can enhance climate resilience and ensure food security.

Key words: *fish farmers, adaptation strategies, multinomial logistics, Bayelsa state, climate change*

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Strengthening Farmer-to-Farmer Knowledge Sharing Networks: A Pathway to Improved Agricultural Extension Service Delivery

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Abstract

The concept of farmer-farmer knowledge sharing was introduced to bridge the extension worker-farmer ratio gap in developing countries. However, the idea was poorly accepted, especially in typical agrarian communities. Therefore, the study explores the concept of a farmer-to-farmer knowledge-sharing network to enhance extension service delivery. The study collected data from 80 farmers randomly selected through a series of multiple stages. The Data was analysed using a 5-point Likert scale and descriptive statistics. The Likert scale results revealed that 62.5% of the farmers are satisfied with farmer-to-farmer knowledge-sharing networks. Moreover, descriptive statistics show that lack of capacity building and low level of education are the most significant problems affecting farmer-farmer sharing networks. The major implication of these findings is that the concept of farmer-farmer knowledge-sharing networks can work better for farmers in developing countries as it was perceived by them as a reliable alternative for information sharing. Therefore, the study recommends introducing incentives into the concept of farmer-farmer knowledge-sharing networks and enhancing the capabilities of farmers who are opinion leaders in the farmer-farmer concept of knowledge-sharing to make it more sustainable.

Keywords: *Agricultural Productivity, Extension, Farmer-to-Farmer, Livelihood and Technology transfer.*
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Ameliorative Effects of *Citrus limetta* raw juice on Cyclophosphamide-Induced Organ Toxicity in Rats

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Abstract

The administration of cyclophosphamide (CYP) as a chemotherapeutic drug has been associated with organ toxicities by generative oxidative stress through its reactive metabolites. Thus, current study is aimed to explore the ameliorative effect of Citrus limetta (CL) raw juice treatment against CYP-induced nephrotoxicity and hepatotoxicity in rats. Following one week acclimatization, female Albino rats (N=24), were equally and randomly divided into four groups: control negative (CN) provided with normal feed and water intake, positive control group (CYP) was given intra-peritoneal injection of CYP at 20mg/kg/bw, positive control group (CL) was given oral CL treatment at 25ml/kg/bw without toxicity induction by CYP and treatment group (CYP+CL) received CL juice (25mL/Kg BW orally) after injection of CYP (20mg/kg intra-peritoneal). After 7 days of treatment, blood and tissue samples were collected and processed for biochemical markers and histopathology of liver and renal tissue. After statistical analyses, our results showed that CL juice significantly ($p \leq 0.05$) restored hepatic serum markers (ALT, AST, and total proteins), renal profile (creatinine, BUN, and uric acid), and cell injury markers (LDH and CK). Histopathological findings further supported biochemical findings and confirmed that CL juice preserved the architectural integrity and restored functions of the liver and kidney. Based on our findings, it is implied that CL may offer hepatic and renal protection by ameliorating oxidative stress produced by CYP administration.

Key Words: Cyclophosphamide, *Citrus limetta*, Nephrotoxicity, Hepatotoxicity.

1. Introduction:

The limited effectiveness of chemotherapy is mainly due to its inability to distinguish between healthy and abnormal tissues, causing widespread damage. This not only reduces the patient's quality of life but also results in life-threatening consequences (Mayne et al., 2006, Manavi et al., 2024). Among these immunosuppressant and antitumor drugs is cyclophosphamide (CYP), which is used to treat a wide range of neoplastic disorders and autoimmune diseases (Jalali et al., 2012, Sinanoglu et al., 2012, Zheng et al., 2022). Generally, CYP requires metabolic activation to exert its metabolic and toxic effects. It is activated in the liver by the hepatic cytochrome p450 oxidase system, leading to the formation of its active metabolites, especially 4-hydroxycyclophosphamide, which exists in equilibrium with aldophosphamide. These metabolites diffuse into the cells and are eventually converted into phosphoramide mustard, a potent DNA alkylating agent that interferes with DNA replication and transcription, ultimately leading to cell death (Hall and Tilby, 1992, Krüger-Genge et al., 2023). In addition to its cytotoxic action on rapidly dividing cancerous cells, the metabolic breakdown of CYP also generates several other toxic metabolic byproducts like acrolein and phosphoramide mustard (Al-Amarat et al., 2022). These metabolites are highly reactive, particularly acrolein generate free radical species. Excessive accumulation of these species results in oxidative stress, which causes damage to lipids, proteins, and nucleic acid within cells (Cengiz et al., 2022). This oxidative stress plays a critical role in causing hepatic (Senthilkumar et al., 2006, Rezaei et al., 2023, Tureyen et al., 2025), and renal toxicities (Ayhanci et al., 2010, Tureyen et al., 2025), associated with CYP administration. Since cyclophosphamide cause organ toxicity primarily through oxidative stress, it is essential to explore natural therapies with strong antioxidant properties to help mitigate its effect.

In this context, the Citrus family plants have been valued for their medicinal properties since the Middle Ages, largely due to their limonoids and flavonoids, which possess antitumor and anti-inflammatory properties (Perez et al., 2010). Citrus fruits are cultivated in more than 140 countries worldwide, with China, Brazil, India, and the United States being the major producing countries (Rao et al., 2021). These fruits are enriched with numerous antioxidative biomolecules, including phenolic acids, flavonones, flavanols, and their derivatives (Dadwal and Gupta, 2023), known to prevent, inhibit, or delay the process of oxidation (Hussain et al., 2018). Oxidation is a biochemical process that leads to the generation of free radicals that may directly or indirectly damage the cellular components (DNA, proteins, etc.) (Zandalinas et al., 2017). Citrus produce an ample quantity of endogenous antioxidants such as carotenoids, ascorbic acid (vitamin C), flavonoids, and tocopherols (vitamin E) (Racchi, 2013). These antioxidants detoxify or reduce the negative effects of reactive oxygen species (ROS), thus protecting the cellular components from ROS damage (Khalid et al., 2022). Furthermore, the potential antioxidant application of Citrus plants has been proven to be beneficial in various oxidative stress disorders, including obesity (Huang et

al., 2020), inflammatory diseases (Rong et al., 2021), atherosclerosis (Hu et al., 2021), neurodegenerative diseases (Cirmi et al., 2021), and cancer (Kitagawa et al., 2021).

As CYP administration is associated with organ toxicity, the current study aims at exploring the ameliorative effects of *Citrus limetta* raw juice against CYP-induced hepatotoxicity and nephrotoxicity in rats.

2. Material and Methods:

2.1. Procurement of materials:

Citrus limetta fruits were procured from the local market in Lahore and identified at the Botany Department of Government College University, Lahore (GC.Herb BOT.3472). Fresh juice was manually extracted daily and stored in a glass bottle at 4°C until use. Cyclophosphamide, available under the brand name Cyclomide (500 mg/1000 mg), was purchased from Sehat Clinic, Lahore.

2.2. Experimental design and animal grouping:

Twenty-four female wistar albino rats (6–8 weeks old, 230–250 g) were acclimatized for one week in the experimental animal facility at the Department of Physiology, University of Veterinary and Animal Sciences (UVAS). The rats were maintained under standard housing conditions, including a 12-hour light/dark cycle, a temperature of 22°C ± 3°C, and 60–70% humidity. They were provided standard chow feed and water *ad libitum.* The Institutional Ethical Committee of UVAS, Lahore approved all experimental procedures (DR #/1326). The rats were randomly and equally divided into 4 groups (n=6) as (a) control negative (CN) rats received basal diet, (b) CYP positive control group received intraperitoneal injection of CYP at 20mg/kg/bw (Kurdi and Alamri, 2016), (c) CL positive control group received orally CL juice at 25 ml/kg/bw (Ezeigwe et al., 2022), and (d) treatment group that was treated with CL juice at 25ml/kg/bw orally following CP 20mg/kg intra-peritoneal injection. Treatment was administered for seven days after CYP induction.

2.3. Body measurements and blood sample collection:

Body weight (g) was measured at the start and end of the experiment. Daily feed consumption (g/day) was measured throughout the trial by using equation 1 (Laaksonen et al., 2013). Body mass index (g/cm^2) was measured by using equation 2 (Bastías-Pérez et al., 2020).

$$\text{Daily feed intake} = Feed\ intake\ (g) - Feed\ leftover\ (g) \qquad Eq.1$$

$$\text{BMI} = \frac{\text{Body Weight(g)}}{\text{Nasoanal Length (cm2)}} \qquad Eq.2$$

At the end of 7-day, the rats in all the groups were sacrificed by cervical dislocation and blood samples from rats was processed into two different vials i.e. clot activator and anticoagulants. Anticoagulant vials were processed for complete hematology analysis by using Abacus Junior Vet hematology analyzer (Diamond Diagnostics Inc. Holliston, US). Procoagulant vials were processed for serum separation. After centrifugation 2000× g for 10 mins, serum was separated and stored at -20°C.

2.4. Biochemical parameters: Determination of hepatic profile

Serum liver parameters included total proteins (TP; Ref#10570) , albumin (A; Ref#10560), globulin (G), albumin-to-globulin ratio A/G ratio, and serum enzymes including aspartate transaminase (AST; Ref#12017), alanine transaminase (ALT; 12117), alkaline phosphatase (ALP; Ref#12117), and gamma-glutamyl transferase (GGT; Ref#12033) were measured using commercially available kits Human Diagnostics, Wiesbaden, Germany were used to assess all the parameters. The readings of these were taken on the Epoch™ microplate reader (Biotek Instruments Inc. Winooski, US).

Globulin levels were measured by using following formula:

$$Globulin\ \left(\frac{g}{dL}\right) = Total\ protein\ \left(\frac{g}{dl}\right) - Albumin\ \left(\frac{g}{dl}\right) \qquad Eq\ 3$$

2.5. Assessment of renal profile:

Renal profile parameters were determined by using commercially available kits by Human Diagnostics, Germany (Creatinine LOT#10053), blood urea nitrogen (BUN; LOT# 16010), and uric acid levels were determined by using (LOT#16005).

2.6. Assessment of cell injury markers:

Serum lactate dehydrogenase (LDH), and creatine kinase (CK) were evaluated by using Commercial kits from Human Diagnostics, Germany, (LOT#16001 for LDH) (LOT# A170245/6 FOR CK).

2.7. Assessment of Lipid profile:

Lipid profile parameters were measured by using human diagnostics, Germany (Total cholesterol LOT# 16008, Triglycerides LOT#16005, and HDL LOT#16002). LDL was measured by using the formula (Nawaz et al., 2024):

$$LDL_c = Total\ cholesterol - HDL_c - \left(\frac{Triglycerides}{5}\right) \qquad Eq\ 4$$

2.8. Histopathology and histomorphometry:

For histopathology, liver and kidney tissue samples were retrieved from 10% formalin and embedded in paraffin to construct blocks. For analysis, 4-5µm thin sections were mounted on albumin-coated slides and stained with hematoxylin and eosin (H&E). Sections were observed under light microscope at 40x magnification. Histomorphometry was performed by using ImageJ software (1.54d, Java 1.8.0_345).

2.9. Statistical analysis:

Data is expressed as the mean ± standard error of mean (SEM). One-way analysis of variance (ANOVA) followed by Tukey's post hoc multiple comparison test to assess the difference between groups. A value of $p \leq 0.05$ were considered statistically significant.

3. Results:

3.1. Anthropometric measurement and analysis:

Anthropometric parameters revealed (Figure 1A-C) that there was a significant (P≤0.05) reduction in body weight (225±12), feed intake (66±2.3), and body mass index (BMI, 0.45±0.04) in the CYP group as compared to control negative group (body weight: 255±11, feed intake: 79±3.2, and BMI: 0.56±0.04), indicating significant anthropometric effects of cyclophosphamide. Whereas, supplementation with Citrus limetta resulted in significant (P≤0.05) restoration of these levels, exhibited in the CYP+CL group (body weight: 240±13, feed intake: 71±2.3, and BMI: 0.51±0.03) showing its protective and restorative effects, potentially mitigating cyclophosphamide-induced metabolic and nutritional disturbance.

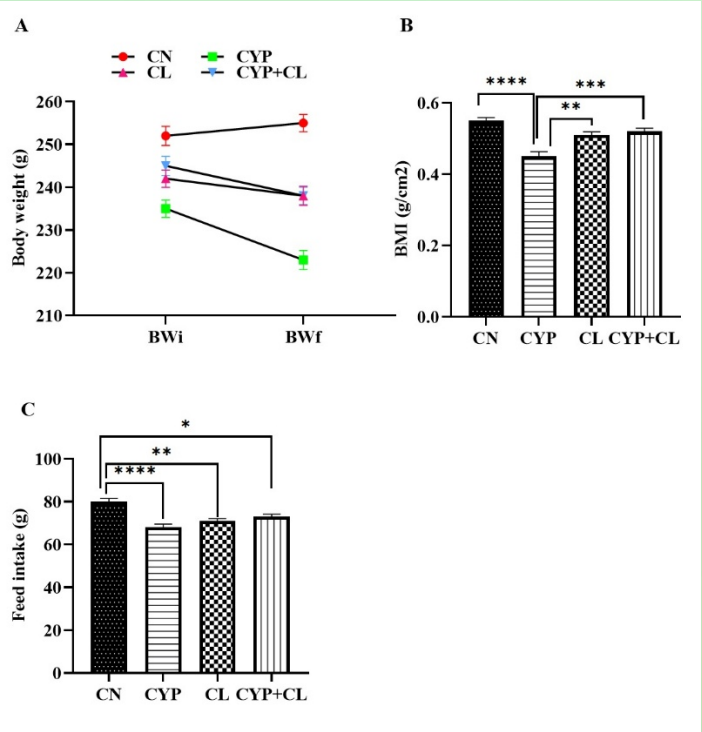


Figure 1. *Citrus limetta* supplementation mitigated cyclophosphamide-induced organ toxicity by improving key anthropometric parameters.

These parameters were evaluated across four groups: the control negative (CN), cyclophosphamide-induced positive control (CYP), *Citrus limetta* control (CL), and the treatment group receiving *Citrus limetta* following cyclophosphamide administration (CYP+CL). These parameters include (A) Body weight, (B) Body mass index (BMI), and (C) Feed intake. Mean±SEM values are displayed on bars, N=6. ****P<0.0001, ***P<0.001, **P<0.01, *P<0.05.

3.2. Hematological analysis and results:

Analyses of hematological parameters revealed significant (P≤0.05) suppression in white blood cells (WBC: 3.2±0.8 10^3/µl), lymphocytes (2.2±0.9 10^3/µl), and platelets (350±21 10^3/µl) in CYP group as compared to the control negative group (WBC: 7.2±2.8, lymphocytes 2.2±0.9, and platelets: 980±23), indicating cyclophosphamide-induced hematotoxicity (Fig 2A-C). However, *Citrus limetta* supplementation significantly (P≤0.05) restored these levels showing its immunomodulatory and hematoprotective properties and mitigating the myelosuppressive effects of cyclophosphamide. Moreover, no significant difference was observed in hematocrit levels (HCT), RBCs, and hemoglobin (Hb) among all groups (Fig 2 D-F).

3.3. Biochemical assessment of liver function:

Liver enzymes and protein levels were analyzed to assess liver function (Fig 3A-F). Cyclophosphamide administration significantly (P≤0.05) elevated ALT (175±13.2), and GGT (1.25±0.34) levels, along with the increase in total proteins levels (7.2±1.01) and decreased albumin to globulin ratio (A/G; 0.67±0.07) as compared to control negative (ALT: 118±12.4, GGT: 0.45±0.21, total proteins: 5.3±1.05, and A/G ratio:1.52±0.03), indicating hepatic toxicity and dysfunction. However, *Citrus limetta* supplementation significantly (P≤0.05) restored these biomarkers showing its potent hepatoprotective potential against cyclophosphamide-induced hepatotoxicity.

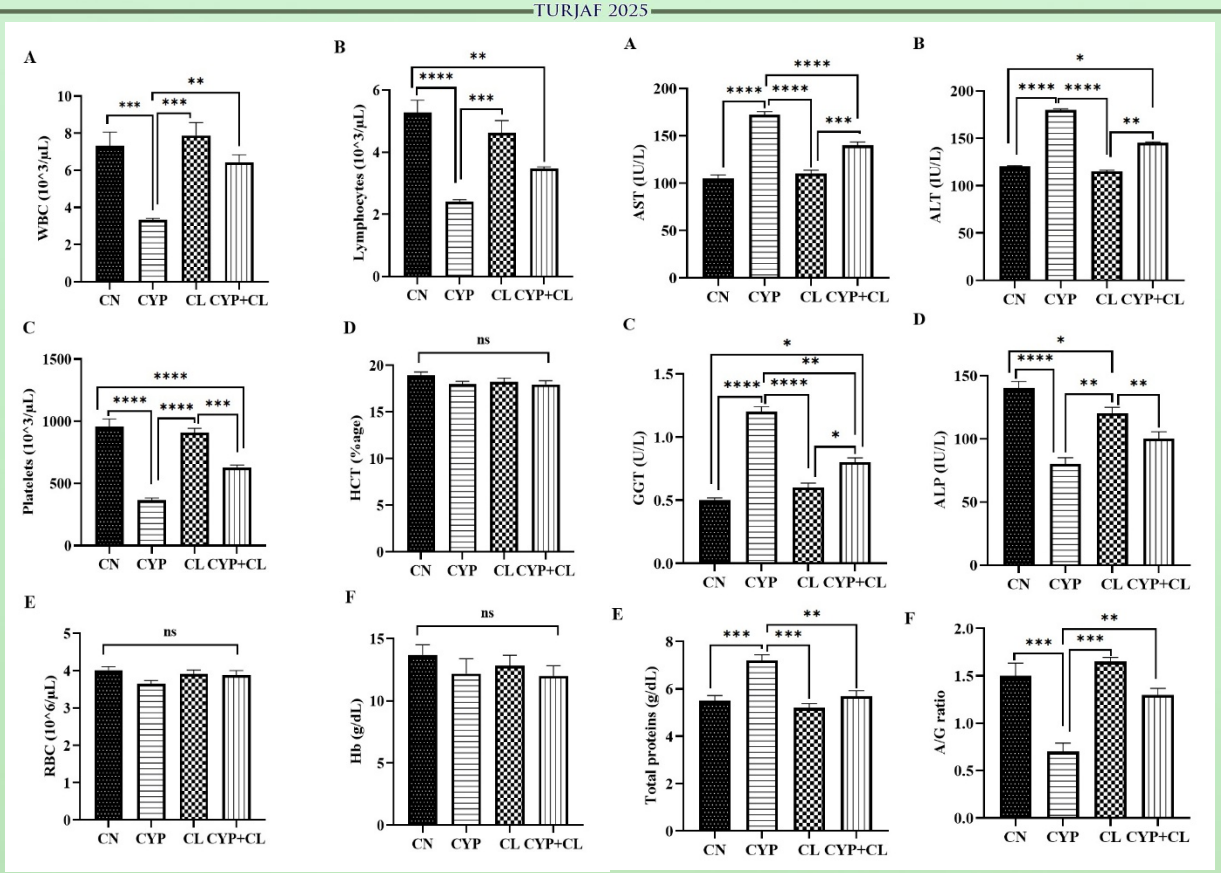


Figure 2. *Citrus limetta* supplementation facilitated hematological restoration against cyclophosphamide-induced organ toxicity.

The following parameters were evaluated across four groups: the control negative (CN), cyclophosphamide-induced positive control (CYP), *Citrus limetta* control (CL), and the treatment group receiving *Citrus limetta* following cyclophosphamide administration (CYP+CL). These parameters include (A) White blood cells (WBC), (B) Lymphocytes, (C) Platelets, (D) Hematocrit (HCT), (E) Red blood cells (RBCs), and (F) Hemoglobin (Hb). Mean±SEM values are displayed on bars, N=6. ****P<0.0001, ***P<0.001, **P<0.01, *P<0.05. ns=non-significant.

Figure 3. *Citrus limetta* supplementation alleviated cyclophosphamide-induced hepatotoxicity by improving liver enzyme profiles and protein homeostasis.

The following parameters were evaluated across four groups: the control negative (CN), cyclophosphamide-induced positive control (CYP), *Citrus limetta* control (CL), and the treatment group receiving *Citrus limetta* following cyclophosphamide administration (CYP+CL). These parameters include (A) AST, (B) ALT, (C) GGT, (D) ALP), (E) Total proteins, and (F) A/G ratio. Mean±SEM values are displayed on bars, N=6. ****P<0.0001, ***P<0.001, **P<0.01, *P<0.05.

3.4. Biochemical assessment of renal function:

Renal function markers including creatinine, blood urea nitrogen (BUN), and uric acid levels were monitored to evaluate renal health (Fig 4A-C). This study revealed a significant (P≤0.05) increase in the levels of creatinine (1.39±0.23), BUN (23.5±3.2), and uric acid (8.5±2.7) in the CYP group as compared to control negative (creatinine: 0.68±0.11, BUN: 13.5±2.3, and uric acid: 5.2±1.9), indicating renal damage. However, *Citrus limetta* effectively mitigated these elevations, reducing creatinine (0.81±0.13), BUN (17.5±2.4), and uric acid (6.1±1.9), indicating its nephroprotective potential against cyclophosphamide-induced nephrotoxicity.

3.5. Biochemical assessment of cell injury markers:

Citrus limetta raw juice consumption alongside cyclophosphamide administration indicated a significant effect (P≤0.05) on lactate dehydrogenase (LDH), and creatine kinase (CK), key markers of cell injury (Fig 5A-B). This study revealed a substantial elevation in LDH (810±18) and CK (126±15) levels in the CYP group compared to normal control (LDH: 570±17, CK: 72±12), indicating increased cellular damage. However, *Citrus limetta* supplementation significantly (P≤0.05) reduced these levels (LDH: 650±12, CK: 83±17), highlighting its cytoprotective potential against cyclophosphamide-induced toxicity.

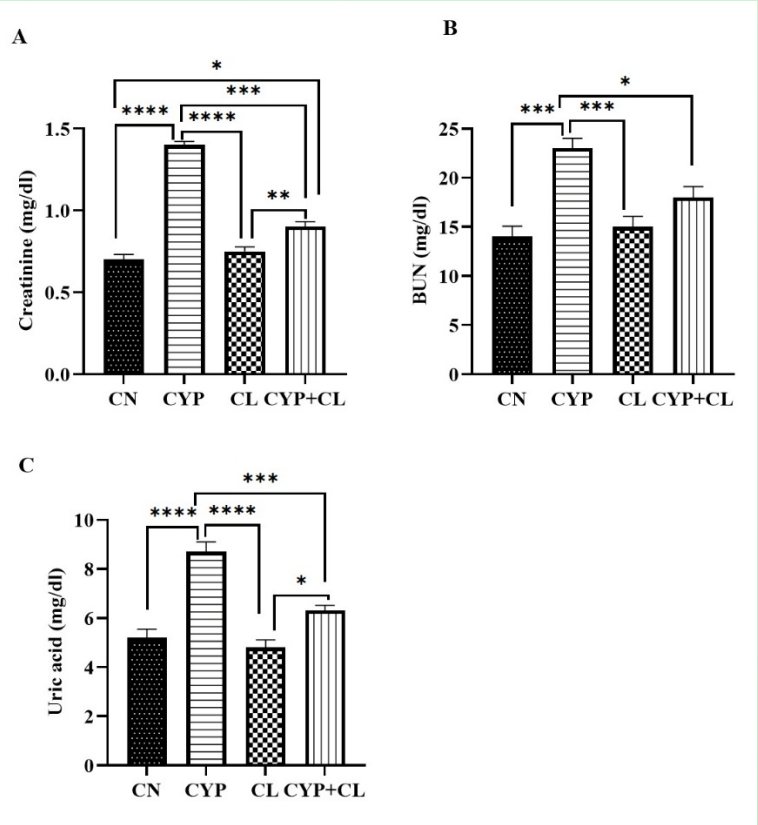


Figure 4. *Citrus limetta* supplementation mitigated cyclophosphamide-induced nephrotoxicity by restoring creatinine, BUN, and uric acid concentrations.

The following parameters were evaluated across four groups: the control negative (CN), cyclophosphamide-induced positive control (CYP), Citrus limetta control (CL), and the treatment group receiving Citrus limetta following cyclophosphamide administration (CYP+CL). These parameters include (A) Creatinine, (B) BUN, and (C) Uric acid. Mean±SEM values are displayed on bars, N=6. ****P<0.0001, ***P<0.001, **P<0.01, *P<0.05.

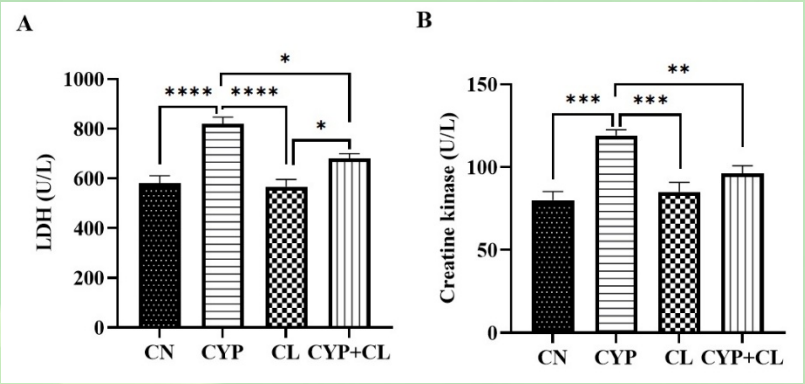


Figure 5. *Citrus limetta* supplementation attenuated cyclophosphamide-induced organ toxicity by reducing cell injury markers.

The following parameters were evaluated across four groups: the control negative (CN), cyclophosphamide-induced positive control (CYP), *Citrus limetta* control (CL), and the treatment group receiving *Citrus limetta* following cyclophosphamide administration (CYP+CL). These parameters include (A) LDH, and (B) Creatine kinase. Mean±SEM values are displayed on bars, N=6. ****P<0.0001, ***P<0.001, **P<0.01, *P<0.05.

3.6. Biochemical assessment of lipid profile:

Lipid profile analyses revealed significant (P≤0.05) dyslipidemia as evidenced by elevation in total cholesterol (149±5.4), and triglycerides (175±4.5) accompanied by a marked reduction in HDL-c (14±1.3) levels in the CYP group (Fig 6A-D), as compared to the control negative group (total cholesterol: 78±4.3, triglycerides: 123±5.7, and HDL-c 25±2.1) showing potential disruption of lipid homeostasis associated with cyclophosphamide. However, supplementation with *Citrus limetta* resulted in the restoration of lipid levels, exhibited in the CYP+CL group, indicative of vital role in mitigating cyclophosphamide-induced dyslipidemia and contributing to lipid profile normalization.

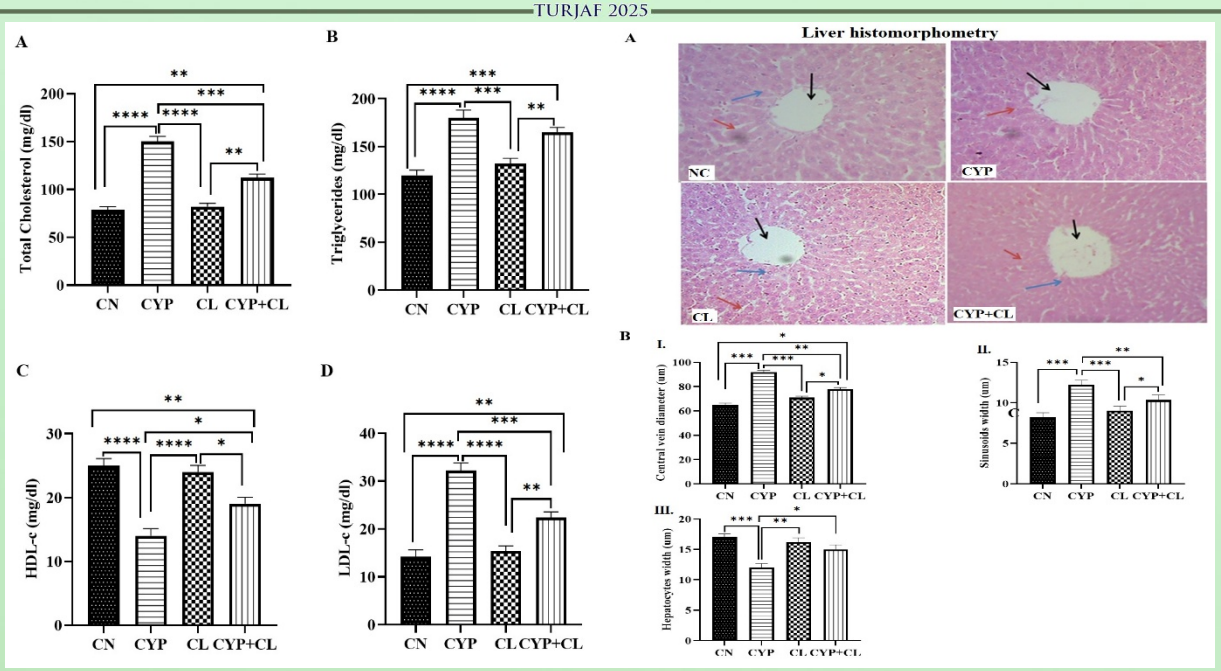


Figure 6. *Citrus limetta* supplementation mitigated cyclophosphamide-induced dyslipidemia by optimizing lipid profile parameters.

The following parameters were evaluated across four groups: the control negative (CN), cyclophosphamide-induced positive control (CYP), *Citrus limetta* control (CL), and the treatment group receiving *Citrus limetta* following cyclophosphamide administration (CYP+CL). These parameters include (A) Total cholesterol, (B) Triglycerides, (C) HDL-c, and (D) LDL-c. Mean±SEM values are displayed on bars, N=6. ****P<0.0001, ***P<0.001, **P<0.01, *P<0.05.

Figure 7. *Citrus limetta* supplementation mitigated cyclophosphamide-induced hepatic damage, preserving liver structure.

(A) Representative photomicrographs of liver sections stained with Hematoxylin and Eosin (H&E) at 40× magnification, illustrating histological variations in different experimental groups: the control negative (CN), cyclophosphamide-induced positive control (CYP), *Citrus limetta* control (CL), and the treatment group receiving *Citrus limetta* following cyclophosphamide administration (CYP+CL). Cyclophosphamide administration led to significant hepatic alterations, including an increased central vein diameter and sinusoidal width, and reduction in hepatocyte size. These structural disruptions were effectively normalized in the Citrus limetta-treated group. Histological analysis (H&E, 40x) highlights central vein dilation (black arrow), sinusoidal congestion (red arrow), and restored hepatocyte morphology (blue arrow) following Citrus limetta supplementation. (B) Quantitative histomorphometric data depicting (I) Central vein diameter, (II) Sinusoid width, and (C) Hepatocyte width. Mean±SEM values are displayed on bars, N=6. ****P<0.0001, ***P<0.001, **P<0.01, *P<0.05.

3.7. Liver histomorphometry:

Liver histopathological analyses (Fig 7A-B) revealed that cyclophosphamide administration induced significant (P≤0.05) hepatic alterations as evidenced by an increased central vein diameter (91±4.2) and sinusoidal width (13.2±0.78), and with a notable reduction in hepatocyte size 12.5±1.07) in CYP group as compared to control negative group (central vein diameter: 63±3.2, sinusoidal width: 7.5±0.89, and hepatocyte diameter: 16.5±1.03). These alterations indicate extensive hepatocellular damage and vascular remodeling, suggesting hepatotoxicity. However, these structural disruptions were effectively normalized in the *Citrus limetta* supplemented group, depicted by CYP+CL, affirming its hepatoprotective potential in maintaining structural integrity of liver against cyclophosphamide-induced hepatotoxicity.

3.8. Renal histopathology:

Histopathological analyses of renal tissue (Fig 8) revealed that cyclophosphamide administration induced structural disruptions as evidenced by increased capsule and glomerular thickness, along with significant dilation of PCT and DCT diameter in the CYP group as compared to the control negative group. Furthermore, CL supplementation resulted in the restoration of glomerular and tubular structural integrity by mitigating cyclophosphamide-induced nephrotoxicity, thereby promoting renal health and functional recovery.

3.9. Renal histomorphometry:

Quantitative histomorphometric analyses of renal tissue revealed significantly (P≤0.05) increased renal corpuscle thickness, increased PCT and DCT diameter, increased PCT wall-to-lumen (W/L) ratio, and significantly decreased DCT W/L ratio in the CYP group (capsule: 85±2.3, PCT W/L: 0.52±0.04, and DCT W/L 0.14±0.03), indicative of nephrotoxicity, as compared to control negative (capsule: 79±1.9, PCT W/L: 0.41±0.03, and DCT W/L 0.19±0.02), and *Citrus limetta* supplemented group (CYP+CL; capsule: 80±1.8, PCT W/L: 0.45±0.05, and DCT W/L 0.21±0.04). These findings imply that *Citrus limetta* possesses strong nephroprotective properties by mitigating cyclophosphamide-induced structural alterations.

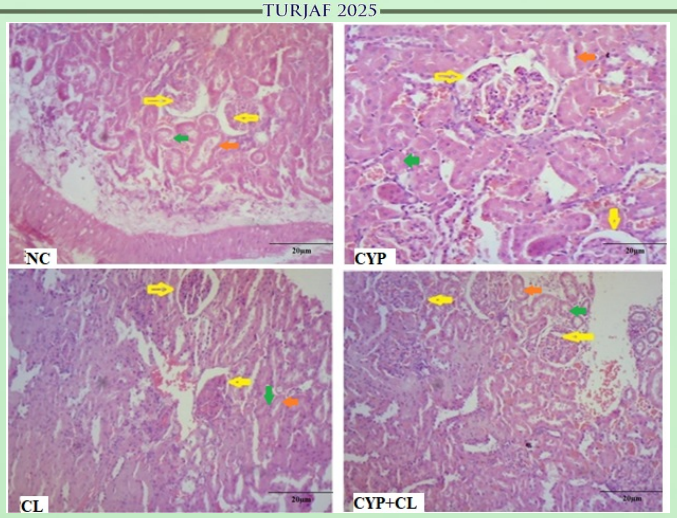


Figure 8. *Citrus limetta* supplementation safeguarded renal tissue integrity by counteracting cyclophosphamide-induced nephrotoxicity.

Representative photomicrographs of renal sections stained with Hematoxylin and Eosin (H&E) at 40× magnification, illustrating histological variations in different experimental groups: the control negative (CN), cyclophosphamide-induced positive control (CYP), *Citrus limetta* control (CL), and the treatment group receiving *Citrus limetta* following cyclophosphamide administration (CYP+CL). Cyclophosphamide exposure resulted in pronounced renal structure disruption including increased capsule and glomerulus thickness, dilation of both proximal (PCT) and distal convoluted tubules (DCT). These pathological alterations were effectively mitigated by *Citrus limetta* supplementation which helped restore renal architecture. Histological features are indicated as follows: renal corpuscle (yellow arrows), proximal convoluted tubules (PCT, orange arrows), and distal convoluted tubules (DCT, green arrows. Scale bar = 20 µm.

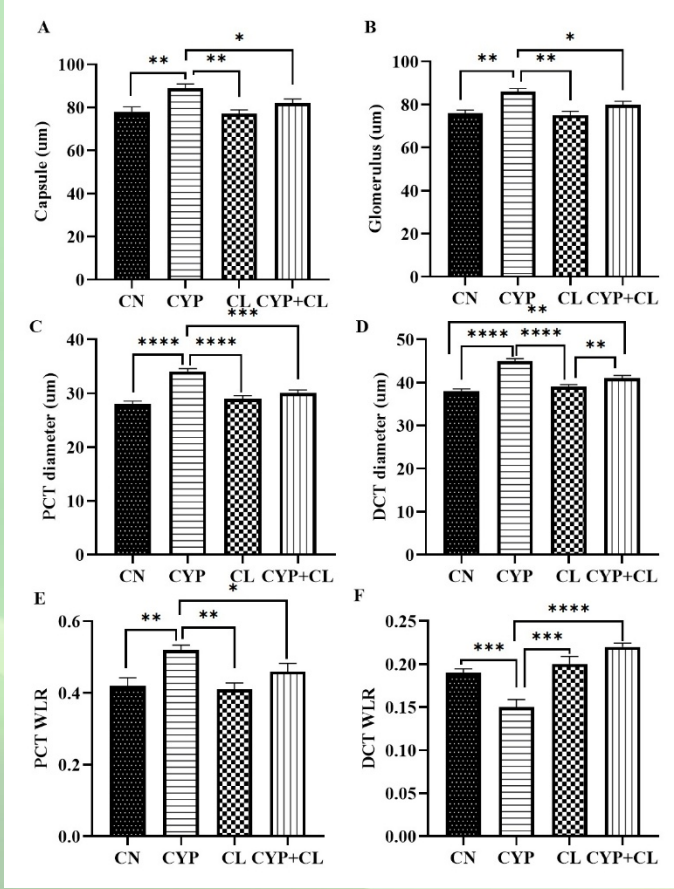


Figure 9. *Citrus limetta* effectively preserved the structural integrity of renal tissues, mitigating cyclophosphamide-induced nephrotoxicity and preventing structural alterations.

Quantitative histomorphometric analysis of renal structural parameters across different experimental groups: the control negative (CN), cyclophosphamide-induced positive control (CYP), *Citrus limetta* control (CL), and the treatment group receiving *Citrus limetta* following cyclophosphamide administration (CYP+CL). Quantitative histomorphometric data depicting: (A) capsule thickness (µm), (B) glomerulus diameter (µm), (C) proximal convoluted tubule (PCT) diameter (µm), (D) distal convoluted tubule (DCT) diameter (µm), (E) PCT wall-to-lumen ratio, and (F) DCT wall-to-lumen ratio. Mean±SEM values are displayed on bars, N=6. ****P<0.0001, ***P<0.001, **P<0.01, *P<0.05.

4. Discussion:

Currently, there is significant research interest in medicinal plants, which confer therapeutic effects, both in modern medicine and allopathy, due to their pronounced antioxidant and antihyperglycemic properties, reduced side effects, and low cost (Nawaz et al., 2024). Among these, the *Citrus* species stands out due to its potent antioxidant and anti-inflammatory properties, which effectively reduce oxidative stress and inflammation __ key contributors to cellular injury and organ damage. Cyclophosphamide, a widely used chemotherapeutic agent induces organ toxicity primarily through oxidative stress. Thus current study is aimed at exploring the protective and restorative effects of *Citrus limetta* raw juice against cyclophosphamide-induced organ toxicity.

Anthropometric data indicated a reduction in body weight, feed intake, and BMI in the CYP group, likely due to the ability of CYP to impair the integrity of the intestinal mucosa, disrupt the morphology of the intestinal villi, increase the permeability of the intestinal mucosal barrier, and resultant nutrient malabsorption leading to weight loss (Zhao et al., 2024). Whereas, supplementation with *Citrus limetta* restored these parameters (**Fig 1A-C**) which could be attributed to its rich flavonoid content. *Citrus* flavonoids, such as naringenin and hesperidin, have been demonstrated to upregulate the expression of tight junction proteins, thereby strengthening the intestinal barrier function and reducing permeability (Stevens et al., 2019, Noda et al., 2013). Thus it is implied that *Citrus limetta* may exert protective and restorative effects on gut health by mitigating CYP-induced intestinal disturbances.

Hematological analysis revealed that CYP remarkably reduced WBC, lymphocytes, and platelets levels in the CYP group likely due to its myelosuppressive effects. CYP disrupts the bone marrow niche by disrupting the interactions between hematopoietic stem cells and their supportive microenvironment, leading to impaired hematopoiesis (Lévesque et al., 2003). Whereas these alterations were restored by *Citrus limetta* (**Fig 2A-F**)which could be due to its strong flavonoid content. As flavonoids have been shown to positively modulate gut microbiota enhancing the production of short-chain fatty acids (SCFAs), which play a crucial role in immune modulation and hematopoiesis (Zhao et al., 2023). Furthermore, no significant effects were seen on hematocrit, hemoglobin, and RBC levels due to selective toxicity of CYP towards rapidly dividing cells. As an alkylating agent, CYP targets rapidly dividing cells by interfering with DNA replication, leading to cell death and immunosuppression (De Jonge et al., 2005). On contrary, mature RBC are non-dividing cells and lack nuclei, rendering them less susceptible to the direct cytotoxic effects of CYP (Sheng et al., 2020). Additionally, RBCs have a longer lifespan, and the study's short duration was insufficient to impact their levels unless severe hemolysis occurred. These findings suggest *Citrus limetta* may exert immunomodulatory effects due to its flavonoid-rich composition.

Liver enzymes profile was monitored to evaluate liver function, as liver is the primary site of drig metabolism, primarily mediated by cytochrome p450 system (Allameh et al., 2023). During CYP metabolism by the liver, acrolein- a highly reactive byproduct, induces excessive free radicals production, overwhelming the liver's antioxidant defenses. These free radicals initiate lipid peroxidation by attacking polyunsaturated fatty acids in cell membranes (May-Zhang et al., 2021), compromise membrane integrity, increasing permeability and ultimately induce hepatocyte injury. Consequently, intracellular enzymes like ALT and GGT leak into the bloodstream, serving as biomarkers of liver dysfunction (Afzal et al., 2023). It was consistent with our findings as AST, ALT, ALP, and GGT levels were significantly raised in CP group along with increased total proteins levels. Whereas these perturbations were restored in CL treated group, as shown in **Fig 3A-F**, which could be attributed to its strong antioxidant activity exerted by flavonoids. Flavonoids are reported to neutralize ROS and inhibit lipid peroxidation, reducing membrane damage and preventing enzyme leakage (restoring **ALT** and **GGT** levels) (Shirani et al., 2020). These restorative activities of CL were further confirmed by histopathology revealing structural preservation, restored central vein diameter, sinusoids width, and hepatocytes diameter as shown in **Fig 7 A-B**. These findings suggest that Citrus species, including *Citrus limetta*, may enhance the liver's antioxidant defenses, thereby aiding in hepatic regeneration and functional recovery.

Serum creatinine, BUN, and uric acid are kidney-specific biomarkers used to monitor renal health. Our findings indicated a significant elevation of these biomarkers after CYP administration (**Fig 4A-C**). Although CYP is an effective chemotherapeutic drug, it has certain toxic effects on different organs like kidneys. Acrolein, a highly toxic metabolite, is filtered by the kidneys and accumulates in the bladder and renal tubules (Hałka et al., 2022). This accumulation directly damages renal tubular cells and causes apoptosis and necrosis (Mohamed et al., 2023). These toxic effects were further confirmed by renal histopathology (**Figure 8-9**)which exhibited glomerular congestion, increased PCT and DCT diameter, and significant tubular damage. These functional and structural alterations were however, ameliorated by *Citrus limetta* juice supplementation which could be attributed to its strong antioxidant defense system, and its citrus-derived compounds known to stabilize podocyte functions (Gong et al., 2023), and ultimately maintain filtration barrier integrity. Thus, *Citrus limetta* protects against CYP-induced nephrotoxicity by enhancing antioxidant defenses and preserving renal structure and function.

Cell injury markers CK and LDH were significantly increased in CYP administered group which indicates widespread tissue injury (**Fig 5A-B**). As explained earlier, CYP metabolism leads to hepatic injury which causes the release of intracellular enzyme LDH leakage into the plasma (Bale et al., 2014). However, an increase in CK levels indicates the myotoxic effects of CYP as seen in some cases of rhabdomyolysis (Shima et al., 2002).

Whereas *Citrus limetta* showed cytoprotective effects due to the presence of vitamin C which enhances levels of glutathione, a key cellular antioxidant in the cellular membrane (Heaney et al., 2008, Metwaly et al., 2022).
The metabolism and physiology of lipids and lipoproteins is a dynamic integrated process with the liver playing a central role in lipid homeostasis. Given the hepatotoxic effects of CYP, the current study revealed that the CYP-administered group showed elevated total cholesterol and triglycerides levels (**Fig 6A-D**) which could be due to the acrolein-lysine adducts known to cause hypertriglyceridemia and hypercholesterolemia by increasing cellular cholesterol accumulation, and by reducing cholesterol efflux by generation of free radicals and inhibition of lipoprotein-lipase (Yahya et al., 2022). *Citrus limetta* exhibited significant hypolipidemic effects, primarily due to its rich flavonoid content. Flavonoids function as cellular signaling molecules, modulating sterol signal transduction pathways, which enhance lipoprotein reuptake and thereby lower circulating LDL levels (Oboh et al., 2014). Thus it is implied that *Citrus limetta* mitigates CYP-induced dyslipidemia by enhancing lipid metabolism and reducing circulating LDL levels through its flavonoid-mediated regulatory effects.

5. Conclusion:

Bases on our findings it is concluded that *Citrus limetta* demonstrated significant protective and restorative effects against cyclophosphamide-induced organ toxicity. Its rich flavonoid content contributed to antioxidant defense, immunomodulation, and lipid metabolism regulation. The juice effectively mitigated CYP-induced hepatotoxicity, nephrotoxicity, dyslipidemia, and myelosuppression by reducing oxidative stress, stabilizing cellular structures, and enhancing metabolic pathways. These findings suggest that *Citrus limetta* holds therapeutic potential in counteracting chemotherapy-induced toxicity, supporting its role as a natural cytoprotective agent.

6. Strengths, limitations and future prospective

This study provides valuable insights into the protective effects of *Citrus limetta* against cyclophosphamide-induced organ toxicity, demonstrating its antioxidant, immunomodulatory, and hypolipidemic potential. The integration of biochemical, hematological, and histopathological analyses strengthens the reliability of the findings. Despite its promising findings, the study has some limitations. The sample size was limited, and the study duration may not have been sufficient to observe long-term protective effects. Additionally, molecular mechanisms underlying the observed protective effects were not extensively explored, warranting further investigation into specific signaling pathways and gene expressions involved.

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ID: 676

GIS-Based on Assessment of Soil Erosion in Bay Region of Somalia

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Abstract

Soil erosion is a major environmental challenge that necessitates meticulous investigation and the implementation of sustainable management practices. The objective of this study is to provide a thorough assessment of soil erosion in the Bay region from 2020 to 2023, utilizing the Revised Universal Soil Loss Equation (RUSLE) and advanced geospatial technologies, particularly Google Earth Engine, to guide sustainable land management strategies. The study integrates multiple datasets, including CHIRPS for rainfall measurement, MODIS for land use analysis, and a digital elevation model for slope calculation, to offer a comprehensive understanding of the factors contributing to soil erosion. The rainfall erosivity (R) factor is calculated using CHIRPS data, while the soil erodibility (K-factor) is derived from the soil dataset. The topographic (LS-factor) is computed using the digital elevation model, and the cover-management (C) and support practice (P) factors are determined from the NDVI and land use data, respectively. The findings reveal considerable spatial variation in soil erosion across the Hirshabelle regions. The results are categorized into five levels based on the severity of soil loss: Slight (<10), Moderate (10-20), High (20-30), very high (30-40), and Severe (>40). While areas classified under “Slight” soil loss are dominant, indicating relatively stable soils, regions under “Severe” soil loss signal potential land degradation and the need for immediate intervention. Furthermore, the study revealed the intricate interplay of slope, vegetation, and land use in influencing soil erosion. Areas with steeper slopes and less vegetation were more susceptible to soil loss, emphasizing the need for targeted soil conservation measures in these regions. The land use factor played a crucial role, with certain land uses contributing more to soil erosion than others.

Keywords: *Soil Erosion, Bay region, RUSLE, Somalia, Google Earth Engine (GEE), GIS*

ID: 677

Determination Of The Best Value Of Organic And Inorganic Minerals To Improve Roughages Values As Animal Feed

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Abstract

The study was conducted in the laboratory of animal sciences Bayero University, Kano to investigate the best value among 7 minerals to improve roughages value feed to cattle. a laboratory trial laid in a 7 x 3 factorial arrangement of a completely randomized design with 7 treatments (Rice straw treated with Sesame salt (T1), Rice straw treated with Doum fruit salt (T2), Rice straw treated with urea (T3), Rice straw treated with potassium (T4), Rice straw treated with poultry waste manure (T5), Rice straw treated with Doum fruit salt+urea (T6) and rice straw alone (T7) as control) and three incubations periods (14, 21 and 28 days) was applied to detect the best mineral and period to improve the nutritional value of rice straw. The source of mineral treatments significantly ($P<0.05$) affected the nutritive value of roughages and 28 days incubation period yielded the highest value for crude protein. The best was obtain from T5, T3, and T2 respectively in term of CP and Nitrogen value.

Key Words: *Tandjile, Roughages, Organinic and inornagic mineral, Rice straw, Treated*

ID: 678

Production And Quality Evaluation Of Marmalade From Orange Fruits Sweetened With Honey

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Abstract

The study evaluated the quality characteristics of the marmalade produced from oranges and honey. In the production of the marmalade, combination of orange and honey were used at different ratios. The ratio of orange to honey were OHM0(100:0) OHM1(80:20), OHM2(70:30), OHM3(60:40) and OHM4(50:50). The marmalade were analyzed for chemical composition, physiochemical, microbiological and sensory properties. Statistical analysis was carried out using one way analysis of variance (ANOVA) and mean was separated using Duncan new multiple range test. The moisture, protein, fat, fibre, ash and carbohydrate ranged from 10.69 - 43.62%, 1.27 - 1.87%, 1.07 - 1.69%, 0.20 - 0.45%, 1.08 - 1.92% and 50.46 - 85.71%, respectively. Sample OHM1 had the highest moisture content. The composition for vitamin A, B3, B1, B2 and C ranged from 0 - 0.45mg/100g, 0.12 - 0.17 mg/100g, 0.47 - 0.71mg/100g, 0.34 - 0.54mg/100g and 16.04 - 24.09mg/100g, respectively. The magnesium, iron and calcium ranged from 34.29 - 39.83mg/100g, 0.58 - 1.02mg/100g and 43.04 - 50.10mg/100g, respectively. The results of the physicochemical parameters for pH and total titrable acid ranged from 2.60 - 3.30, 0.95 - 1.28. Total viable count and the mould count were not detected in the samples. Sensory scores indicated that the marmalade with 80% orange, 20% Honey was most accepted by consumers amongst other formulations, resulting in improved taste and texture. Overall, the use of honey in the production of marmalade is a promising approach for producing nutritious and acceptable fruit beverage.

Key words: *Production, evaluation, marmalade, orange, honey*

ID: 679

Impact of Storage Conditions on the Stability and Bioactivity of Date Vinegar: A Comprehensive Study on Its Efficacy in Managing Metabolic Diseases

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Abstract

Date vinegar, a functional beverage derived from dates (*Phoenix dactylifera*), has garnered attention for its potential health benefits, including antidiabetic and cardiovascular effects. This study investigates the efficacy of date vinegar in managing type 2 diabetes mellitus (T2DM) and cardiovascular diseases while also examining how different storage conditions influence the stability and bioactivity of the beverage. In the first phase, a 10-week randomized controlled trial was conducted to assess the clinical effects of date vinegar on glycemic control and lipid profiles in adults with T2DM and dyslipidemia. Significant improvements were observed in HbA1c, LDL cholesterol, and fasting blood sugar levels ($p < 0.05$). Complementary computational docking and molecular dynamics simulations identified binding interactions between key bioactive compounds in date vinegar and therapeutic protein targets, such as ACE, β1AR, and DPP-IV. In the second phase, the stability of date vinegar was tested under different storage conditions. A beverage was prepared by blending date vinegar and goji berry juice, then stored at three different temperatures (room temperature, 40°C, and 50°C) for one and two months. Changes in physicochemical and phytochemical parameters were monitored, including total sugar content, antioxidant activity, and phenolic content. After two months, an electronic nose analysis was performed to evaluate sensory changes under different storage conditions. The results indicated that higher temperatures (40°C and 50°C) negatively affected the integrity of bioactive compounds, whereas storage at room temperature better preserved the beverage's quality. When stored appropriately, this integrated study demonstrates that date vinegar provides a dual-target therapeutic strategy for managing T2DM and cardiovascular diseases. The clinical findings confirm its efficacy, while the storage conditions emphasize the importance of proper storage to maintain its bioactive properties for optimal therapeutic benefits.

Key Words: *Date vinegar, Storage conditions, Bioactive compounds, Type 2 diabetes, Cardiovascular diseases, Stability, Molecular dynamics simulations, Glycemic control.*

ID: 680

Nutritional, Medicinal, and Industrial Applications of Tokma (*Hyptis suaveolens*), Isabgol (*Plantago ovata*), and Chia (*Salvia hispanica*): A Comprehensive Review

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Abstract

Herbal plants offer three significant benefits: nutritional support, disease treatment, and industrial utility. For centuries, they have been valued for their beneficial properties. Among them, Tokma (*Hyptis suaveolens*), Isabgol (*Plantago ovata*), and Chia (*Salvia hispanica*) are well known and widely used for multiple health benefits and diverse applications. This review aims to provide a comprehensive overview of the nutritional, medicinal, and industrial use of *Hyptis suaveolens*, *Plantago ovata*, and *Salvia hispanica*, thereby facilitating further research and understanding. A systematic review of peer-reviewed articles was conducted, supplemented by self-exploration. The study highlights that *Plantago ovata* is notable for its high fiber content and positive impact on gut health, making it widely used in dietary supplements and animal feed. It can also be researched for its application in green food packaging and emulsion-based drug delivery systems. *Salvia hispanica* is rich in omega-3 fatty acids and essential minerals and is especially valued for its cardiovascular and metabolic health benefits. It is used largely in bakery products, beverages, and cosmetics. Although *Hyptis suaveolens* is less researched globally, it shows significant medicinal potential, including anti-inflammatory, antiviral, antimicrobial, and blood purifying properties. Its oil has potential insecticidal properties and may be used in agriculture as a natural herbicide or grain preservative. In conclusion, *Salvia hispanica* is more nutritionally balanced and has more diversified use compared to the other two. Nevertheless, *Hyptis suaveolens* and *Plantago ovata,* also offer diverse health benefits and applications. Further studies are essential to fully explore their potential and uses.

Keywords: *Hyptis suaveolens, Plantago ovata, Salvia hispanica, Medicinal, Nutritional, Industrial application*

ID: 681

Comparison of Setae Morphology of Both Sexes of *Oxyopes ramosus* (Martini & Goeze, 1778) (Araneae, Oxyopidae)

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Abstract

In this study, setae morphology on the prosoma, opisthosoma and legs of male and female individuals of *Oxyopes ramosus* (Martini & Goeze, 1778) from the spider family Oxyopidae was determined by Scanning Electron Microscopy (SEM). It was seen that a scaly type setae, which is specific to the genus, was also present in this species, but this setae type showed slight differences in male and female individuals of this species. This is also the first study to compare the setae morphology in both sexes of *Oxyopes ramosus* (Martini & Goeze, 1778).

Key Words: *Oxyopes*, Setae morphology, Spider, Türkiye.

Introduction

Spiders are one of the most successful organisms in the arachnids (Arachnida) class of the arthropods (Arthropoda), adapted to terrestrial ecosystems. Most of the spiders, which are mostly adapted to terrestrial habitats, live on the ground, on or in the soil surface, in stony areas, rocky areas and on herbaceous or woody plants. Very few of them live on the edges and near the surface of fresh water. They are carnivorous creatures and with this feature, they show dominant feature in the ecosystem (Foelix, 2011). They usually feed on insects, but they can also eat each other. Since insects constitute the majority of their diet, they are used as biological control agents in agricultural ecosystems (Bayram and Allahverdi, 1999).

The outer part of the body of spiders consists of a hard layer of chitin and scleroprotiene, called the cuticle. The cuticle is covered with hair-like structures called setae, which fulfil various tasks. Setae are usually concentrated on the abdomen, but are also found on the prosoma, legs, palps and ducklings. The linear setae are usually associated with a receptor cell and act as sensory organs or mechanoreceptors, whereas the scale-like ones are not associated with any receptor cell and act only as a covering (Zakharov and Ovtsharenko, 2015).

Among all spider families, 13 families (Anyphaenidae, Araneidae, Corinnidae, Gnaphosidae, Heteropodidae, Liocranidae, Lycosidae, Oxyopidae, Philodromidae, Pisauridae, Salticidae, Thomisidae and Uloboridae) had at least one type of seta. Studies on the seta morphology of ground spiders revealed the presence of 10 different cover setae and it was stated that the diversity of these seta morphologies can be used in the classification of spiders at the genus and species level (Lehtinen, 1975).

The first aim of this study was to determine the seta morphology of *Oxyopes ramosus* belonging to the family Oxyopidae. The second aim of the study was to make a comparison of the morphological structures of the setae in male and female individuals of this species.

Materials and Methods

Materials

The male and female individuals of *Oxyopes ramosus* belonging to the family Oxyopidae used in this study were obtained from Niğde Ömer Halisdemir University Arachnological Museum (NOHUAM) (Figure 1).

Methods

The Electron Microscope in the Central Research Laboratory of Niğde Ömer Halisdemir University was used to determine the seta morphology of male and female individuals of Oxyopes ramosus. The prosoma, opisthosoma and legs of each individual were placed on staps and the surface of the specimens were coated with gold using a Sputter Coater (Cressingto Auto 108). Photographs were taken using EVO LS 10 ZEISS brand device (Figure 2).

Results and Discussion

The morphology of the setae on the prosoma, opisthosoma and segments of both sexes of *O. ramosus* (Martini & Goeze, 1778) belonging to the *Oxyopes* species of the Oxyopidae family was determined by SEM. The SEM photographs obtained are given below (Figures 3,4).



Figure 1. General Habitus of *Oxyopes ramosus* species



Figure 2. EVO LS 10 ZEISS brand SEM device

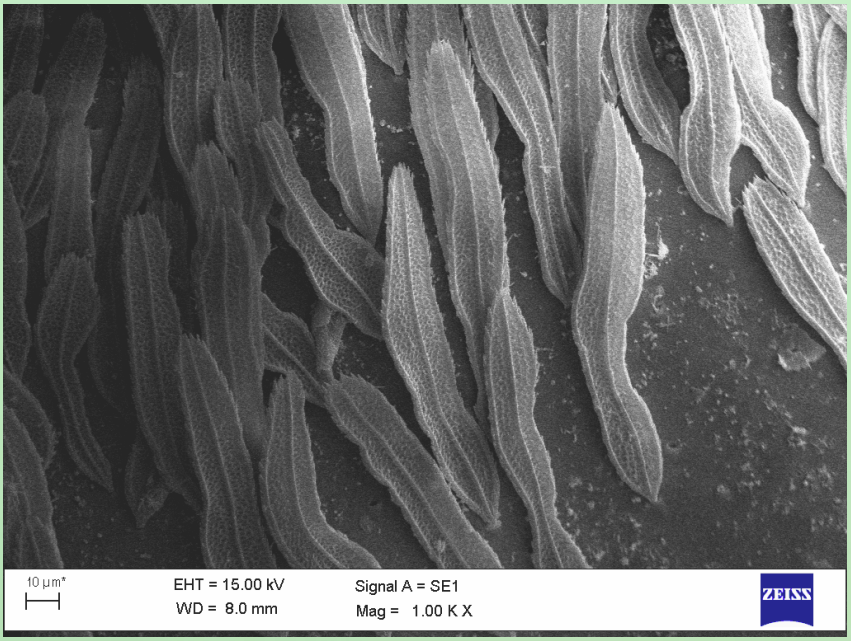


Figure 2. Setae of the female specimen of *Oxyopes ramosus* (Martini & Goeze, 1778)

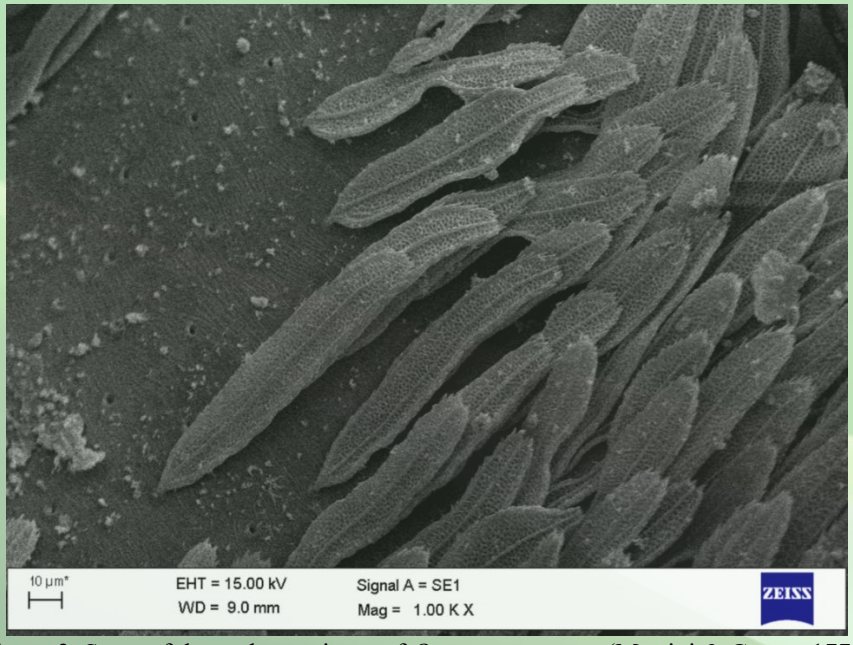


Figure 3. Setae of the male specimen of *Oxyopes ramosus* (Martini & Goeze, 1778)

The bodies of most lynx spiders are covered with cuticular structures called setae. These setae are more densely located on the dorsal and lateral parts of the prosoma and abdomen. It is thought that these setae covering the body have defense, heat regulation and communication functions. In lynx spiders, studies have been conducted on the seta morphologies of the *Oxyopes* and *Peucetia* genera so far (Townsend Jr and Felgenhauer, 2001). In the studies conducted, setae with a scaly morphology were observed in *Oxyopes aglossus* and *O. salticus*. Another genus belonging to the Oxyopidae family, the *P. viridans* species belonging to the *Peucetia* genus, had a hairy type seta morphology (Townsend Jr and Felgenhauer, 2001).

In Türkiye, the family Oxyopidae is represented by 2 genera and 7 species. One of these two genera, *Oxyopes*, is represented by subspecies, these are *Oxyopes globifer* Simon, 1876, O. heterophthalmus (Latreille, 1804), *O. lineatus* Latreille, 1806, *O. nigripalpis* Kulczyński, 1891, *O. pigmentatus* Simon, 1890 and *O. ramosus* (Martini & Goeze, 1778) (Danışman et al., 2023). Among these species, in this study, SEM photographs were made on both male and female individuals of *O. ramosus* (Martini & Goeze, 1778).

According to the literature, the seta morphology of six *Oxyopes* species has been studied so far and all of them have the same morphological type of scaly setae. This *Oxyopes* genus-specific scaly seta type shows marginal and apical spines with a single shaft and abundant plicae Townsend and Felgenhauer, 2001). In this study, SEM photographs of both male and female individuals of *O. ramosus* (Martini & Goeze, 1778) showed that although the seta morphology of the male and female were largely similar, there were differences in the apical spines of the seta (Figure 4).

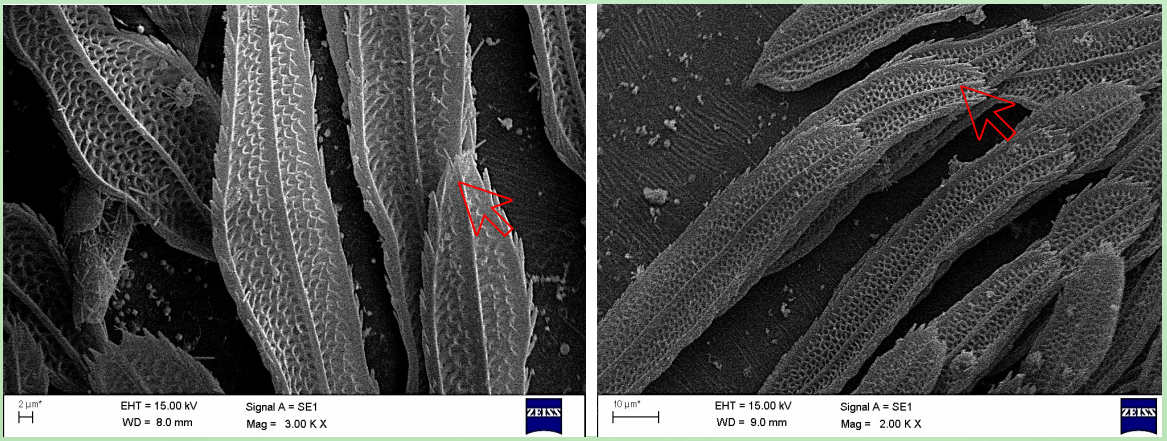


Figure 4. Differences in seta morphology in males and females of *O. ramosus*

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ID: 682

Food Waste Prevention Training: Content Determination

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Abstract

Food waste is one of the most important issues facing the food and beverage industry today. Food waste means that about one-third of the food produced worldwide is lost before it reaches the consumer. In Turkey, millions of tons of food are wasted every year, and a significant portion of this occurs in the food and beverage sector. Food and beverage businesses play a critical role in preventing waste at every step from the supply chain to the service stage. Raising the awareness of sector employees is one of the most important steps to be taken to solve this problem. A training content should be developed on this subject and awareness of food waste in society and individuals should be increased and ways to contribute to minimizing waste should be presented. The content should emphasize the causes of food waste, its consequences and strategies to reduce it. At the beginning, food waste should be defined and its dimensions should be detailed. The current state of food waste both in the world and in Turkey, supported by current statistics, should be presented to the participants. In this way, participants can reach a better level of awareness to grasp the seriousness of this important problem. One of the other main topics that should be covered within the framework of the training is the root causes of waste. Themes such as consumer behavior, deficiencies or malpractices in production and distribution processes, storage and handling errors should be emphasized. Each cause should be examined in detail and clarified with concrete examples of common mistakes. Strategies to prevent food waste constitute the most vital part of the training. Participants should be given practical advice on proper buying habits, storage techniques and how to utilize leftovers. At the same time, information should be provided on policies and concert projects that can be implemented on a larger scale. Finally, trainings should be interactive and planned to provide opportunities for active participation. Group activities, debates and case studies can be used to engage participants and make the training effective. The ultimate goal of this program is to bring about lasting behavioral changes in individual lives in relation to food waste.

Key Words: *Food waste, Education, Food waste prevention*

Gıda İsrafını Önleme Eğitimi: İçerik Belirleme

Özet

Gıda israfı, günümüzde yiyecek içecek sektörünün karşı karşıya kaldığı en önemli sorunlardan biridir. Gıda israfı, dünya genelinde üretilen gıdaların yaklaşık üçte birinin tüketiciye ulaşmadan kaybedilmesi anlamına gelmektedir. Türkiye'de her yıl milyonlarca ton gıda çöpe gitmekte ve bunun önemli bir kısmı yiyecek içecek sektöründe gerçekleşmektedir. Yiyecek içecek işletmeleri, tedarik zincirinden servis aşamasına kadar her adımda israfın önlenmesinde kritik rol oynamaktadır. Sektör çalışanlarının bilinçlendirilmesi, bu sorunun çözümü için atılacak en önemli adımlardan biridir. Bu konuda bir eğitim içeriği geliştirilmeli ve toplumda ve bireylerde gıda israfı konusundaki farkındalığı artırılmalı ve israfın en aza indirgenmesine katkı sağlayacak yollar sunulmalıdır. İçerik olarak, gıda israfının nedenleri, oluşturtuğu sonuçlar ve azaltılması için geliştirilen stratejilere vurgu yapılmalıdır. Başlangıçta gıda israfının tanımı yapılmalı ve boyutları detaylandırılmalıdır. Hem dünyada hem de Türkiye'de gıda israfının mevcut hali, güncel istatistiklerle desteklenip katılımcılara sunulmalıdır. Böylece katılımcılar, bu önemli sorunun ciddiyetini kavrama noktasında daha iyi bir bilinç düzeyine ulaşabilirler. Eğitimin çerçevesinde işlenmesi gereken diğer ana konulardan biri, israfın kökeninde yatan nedenlerdir. Tüketici davranışları, üretim ve dağıtım süreçlerindeki eksiklikler veya yanlış uygulamalar, saklama ve depolama hataları gibi temalar üzerinde durulmalıdır. Her bir neden ayrıntılı incelenmeli ve yanlara sık karşılaşılan hatalar üzerinden somut örneklerle açıklığa kavuşturulmalıdır. Gıda israfını engellemek adına geliştirilen stratejiler ise eğitimin en hayati bölümünü oluşturur. Katılımcılara doğru alım alışkanlıkları, saklama teknikleri ve yemeklerin artıkları nasıl değerlendirilebilir gibi konular hakkında pratik öneriler verilmelidir. Aynı zamanda, daha geniş ölçekte uygulanabilecek politikalar ve konser projeler hakkında bilgi aktarılmalıdır. Son olarak, eğitimler interaktif bir yapıya sahip olmalı ve katılımcılara aktif katılım imkanları sunacak şekilde planlanmalıdır. Grup aktiviteleri, münazara ortamları ve vaka çalışmaları gibi yöntemlerle katılımcıların ilgisini çekmek ve eğitimi etkili hale getirmek arzulanan düzeyde mümkündür. Bu programın nihai hedefi, bireysel hayatlarda gıda israfı ile ilgili kalıcı davranış değişimlerini sağlamaktır.

Anahtar Kelimeler: *Gıda israfı, Eğitim, Gıda israfı önleme*

Giriş

Gıda israfı, günümüzde yiyecek içecek sektörünün karşı karşıya kaldığı en önemli sorunlardan biridir. Bu eğitim, işletme çalışanlarının israfı önleme konusunda bilinçlenmesini ve pratik becerileri kazanmasını hedeflemektedir.

Gıda israfı, dünya genelinde üretilen gıdaların yaklaşık üçte birinin tüketiciye ulaşmadan kaybedilmesi anlamına gelmektedir. Türkiye'de her yıl milyonlarca ton gıda çöpe gitmekte ve bunun önemli bir kısmı yiyecek içecek sektöründe gerçekleşmektedir.

Yiyecek içecek işletmeleri, tedarik zincirinden servis aşamasına kadar her adımda israfın önlenmesinde kritik rol oynamaktadır. Sektör çalışanlarının bilinçlendirilmesi, bu sorunun çözümü için atılacak en önemli adımlardan biridir.

Bu çalışmanın amacı gıda israfının en yaygın görülen yiyecek ve içecek işletmelerinde, işletme çalışanlarına verilebilece gıda israfını eğitiminin içeriğini belirlemektedir.

Gıda İsrafını Önleme Eğitimin Amacı ve Hedefleri

Bu eğitim programı, yiyecek içecek işletmelerinde çalışan tüm personelin gıda israfını önleme konusunda aktif rol almasını sağlamayı amaçlamaktadır. Eğitim sonunda, çalışanların kendi pozisyonlarında israfı nasıl azaltabileceklerine dair somut adımlar atabilmeleri hedeflenmektedir.

a. Farkındalık Oluşturma: Çalışanların gıda israfının boyutları, nedenleri ve etkileri konusunda bilinçlendirilmesi ve sorumluluk duygusunun geliştirilmesi
b. Bilgi ve Beceri Kazandırma: İsrafı azaltmaya yönelik temel prensiplerin, tekniklerin ve uygulamaların öğretilmesi
c. Davranış Değişikliği Sağlama: Edinilen bilgilerin günlük iş akışına entegre edilmesi ve sürdürülebilir alışkanlıklar oluşturulması

Gıda İsrafının Tanımı ve Türleri

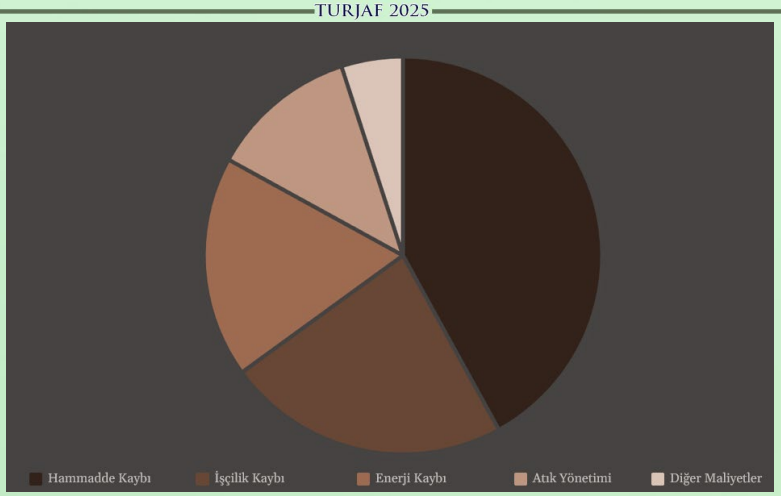
Gıda israfı, insan tüketimine uygun olan yiyeceklerin çeşitli sebeplerle tüketilmeden atılması olarak tanımlanmaktadır. Yiyecek içecek işletmelerinde israf, tedarik zincirinin her aşamasında meydana gelebilmektedir.

Türkiye'deki işletmelerde en çok görülen israf türü, porsiyon kontrolündeki yetersizliklerden kaynaklanmaktadır. Bunu hazırlık aşamasındaki kayıplar ve uygun olmayan depolama koşulları takip etmektedir. İsraf türlerinin doğru tanımlanması, etkili önleme stratejilerinin geliştirilmesi için kritik öneme sahiptir.

Gıda İsrafının Ekonomik Etkileri

Gıda israfı, yiyecek içecek işletmelerini doğrudan ve dolaylı ekonomik maliyetlerle karşı karşıya bırakmaktadır. Ortalama bir restoranda, toplam maliyetlerin %2-10'u israf edilen gıdalardan kaynaklanmaktadır. Bu durum, işletmelerin kâr marjlarını önemli ölçüde etkilemektedir.

İsrafın azaltılması, işletme maliyetlerini düşürmenin yanı sıra, sektörel rekabet gücünü artırmakta ve ulusal ekonomiye katkı sağlamaktadır. Uluslararası araştırmalar, gıda israfını %20 oranında azaltan işletmelerin yıllık kârlarını ortalama %30 artırabildiklerini göstermektedir.



Şekil 1. Gıda İsrafının Ekonomik Etkileri

Gıda İsrafının Çevresel Etkileri

Gıda israfının çevresel etkileri, genellikle gözle görülmediği için göz ardı edilebilmektedir. Ancak, israf edilen her gıda maddesi, üretiminden atık haline gelene kadar çevre üzerinde ciddi bir yük oluşturmaktadır.

- Karbon Ayak İzi: Atılan her kilogram gıda, üretiminden atık haline gelene kadar yaklaşık 4.5 kg karbondioksit salınımına neden olmaktadır. Türkiye'deki yiyecek içecek sektörünün israftan kaynaklanan karbon ayak izi yıllık 2.3 milyon ton CO2 eşdeğeridir.
- Su Ayak İzi: İsraf edilen her kilogram gıda için üretim sürecinde ortalama 1500 litre su kullanılmaktadır. Sektördeki israf, yılda milyarlarca litre suyun boşa harcanması anlamına gelmektedir.
- Biyoçeşitlilik Kaybı: Gıda üretimi için yapılan tarım faaliyetleri habitat kayıplarına yol açmakta, israf ise bu etkiyi gereksiz yere artırmaktadır. Türkiye'deki endemik türlerin %15'i tarım alanlarının genişlemesinden olumsuz etkilenmektedir.

Gıda Güvenliği ve İsraf İlişkisi

Gıda güvenliği ve israf arasında doğrudan bir ilişki bulunmaktadır. Güvenli olmayan gıdaların tüketilememesi ve imha edilmesi gerektiği açıktır, ancak uygun saklama ve işleme koşullarıyla pek çok gıdanın güvenli kalma süresi uzatılabilir.

- Uygun Olmayan Saklama Koşulları: Sıcaklık kontrolü yapılmayan depolarda ürünlerin hızla bozulması ve atık haline gelmesi. Soğuk zincirin kırılması sonucu et ve süt ürünlerinde oluşan mikrobiyolojik riskler.
- Son Kullanma Tarihi Yönetimi: TETT (Tavsiye Edilen Tüketim Tarihi) ve SKT (Son Kullanma Tarihi) arasındaki farkın bilinmemesi nedeniyle güvenli gıdaların israf edilmesi. Etiketleme hatalarından kaynaklanan gereksiz imhalar.
- Çapraz Kontaminasyon: Çiğ ve pişmiş gıdaların aynı alanlarda muhafaza edilmesi sonucu oluşan bulaşmalar. Kontamine olmuş gıdaların zorunlu olarak atılması ve ekonomik kayıp.

Satın Alma, Tedarik Zinciri ve Stok Yönetimi

Etkili bir satın alma ve tedarik zinciri yönetimi, gıda israfını kaynağında önlemenin en etkili yollarından biridir. Doğru miktarda ve kalitede ürün temin edilmesi, işletme içindeki diğer israf önleme çabalarının da temelini oluşturmaktadır. Türkiye'deki başarılı işletmeler, mevsimsel ürünleri menülerine dahil ederek hem tazelik ve lezzet avantajı elde etmekte hem de israfı azaltmaktadır. Tedarikçilerle kurulan güçlü iş birlikleri sayesinde, standart dışı ancak tüketilebilir ürünler değerlendirilebilmekte ve ekonomik kazanç sağlanmaktadır.

- Bu süreçte satın alma ve tedarik zincirinin daha sağlıklı yürütülebilmesi için ihtiyaç analizi, sipariş yönetimi, tedarikçi seçimi ve teslimat kontrolü aşamaları iyi takip edilmelidir.
- Gerçek ihtiyaçların belirlenmesi ve satış tahminlerinin doğru yapılması. Geçmiş verilerden yararlanarak mevsimsel değişimlerin öngörülmesi ve sipariş miktarlarının optimize edilmesi
- Minimum sipariş miktarlarının optimizasyonu ve sık aralıklarla küçük siparişler verilmesi. Özel anlaşmalarla iade ve değişim koşullarının iyileştirilmesi.
- Sürdürülebilir üretim yapan, kaliteli ve standart ürünler sunan tedarikçilerin tercih edilmesi. Yerel üreticilerle çalışarak tazelik ve teslimat sürelerinin iyileştirilmesi.
- Gelen ürünlerin kalite ve miktar kontrollerinin titizlikle yapılması. Tedarikçilerle sürekli iletişim halinde olunması ve geri bildirimlerin paylaşılması.

Stok yönetimi yiyecek içecek işletmelerinde gıda israfının azaltılmasında önemlidir. Türkiye'deki işletmelerde yapılan araştırmalar, FIFO (ilk giren ilk çıkar) prensibinin doğru uygulanması durumunda depolama kaynaklı israfın %60'a varan oranlarda azaltılabildiğini göstermektedir. Dijital stok takip sistemlerinin kullanılması, insan hatalarını azaltarak verimlilik artışı sağlamaktadır.

Menü Planlaması, Porsiyon Kontrolü ve Servis Teknikleri

Doğru menü planlaması ve porsiyon kontrolü, işletmelerin hem maliyetleri düşürmesine hem de müşteri memnuniyetini artırmasına olanak sağlar. İyi tasarlanmış bir menü, minimum atıkla maksimum verim elde etmeyi mümkün kılar. Türkiye'deki önde gelen restoran zincirleri, esnek menü yapıları sayesinde stok fazlası ürünleri değerlendirerek israfı önlemekte ve kârlılıklarını artırmaktadır. Porsiyon kontrolü yapan işletmelerde, tabak artıklarının %30'a varan oranlarda azaldığı gözlemlenmiştir.

Servis aşaması, gıda israfının en görünür şekilde ortaya çıktığı noktadır. Tabak artıkları, müşteri tarafından yenmeyen ve doğrudan çöpe giden gıdaların başında gelmektedir. Etkili servis teknikleri, müşteri memnuniyetini korurken israfı minimize etmeyi amaçlar. Açık büfelerde küçük servis kaplarının kullanılması ve sık aralıklarla yenilenmesi, hem tazeliği artırmakta hem de büfenin her zaman dolu görünmesini sağlarken daha az gıdanın israf edilmesine olanak tanımaktadır. Ayrıca, müşterilere paket servis opsiyonu sunmak, yenmeyen yemeklerin değerlendirilmesini sağlamaktadır. Tabak tasarımında daha az garnitür kullanılması ve yenilebilir süslemelerin tercih edilmesi, görsel estetiği korurken israfı azaltmaktadır. Türk mutfağının geleneksel sunumları, genellikle sade ve fonksiyoneldir, bu yaklaşım modern işletmelerde de benimsenmelidir.

Çalışan Eğitimi ve Motivasyonu

Çalışanların eğitimi ve motivasyonu, israf önleme stratejilerinin başarısında belirleyici rol oynar. İsrafı önleme bilincine sahip ve bu konuda motive olmuş bir ekip, işletmenin her aşamasında fark yaratabilir. Türk yiyecek içecek sektöründe yapılan araştırmalar, düzenli eğitim alan ve ödüllendirme sistemleriyle desteklenen personelin, israfı %50'ye varan oranlarda azaltabildiğini göstermektedir. Çalışanların sürece dahil edilmesi ve fikirlerinin değerlendirilmesi, aidiyet duygusunu güçlendirerek motivasyonu artırmaktadır. Çalışanlara düzenli olarak departmana özel eğitim programları, yeni başlayanlar için oryantasyon programları ve üst yönetim için farkındalık ve liderlik eğitimleri düzenlemek gıda israfının orta vadeli adımları arasında yer almalıdır. Ayrıca işletme içi açık iletişim kanallarının oluşturulması, çalışanlardan gelen iyileştirme önerilerinin değerlendirilmesi, düzenli toplantılarla israf verilerinin paylaşılması ve başarı hikayelerinin tüm ekiple paylaşılması bu eğitimlerin parçası olmalıdır. Bunun yanı sıra personel içinde gıda israfını azaltma hedeflerine ulaşan ya da konu ile ilgili inovatif çözümler sunan personelin ya da ekiplerin takdir edilmesi motivasyonu artıracak ve israf konusunda bilinç kültürünü oluşturacaktır.

Sonuç

Gıda israfının önlenmesi, karmaşık ve çok boyutlu bir sorun olmasına rağmen, sistematik bir yaklaşımla önemli ölçüde azaltılabilir. Bu eğitim içeriğinde ele alınan stratejiler ve teknikler, işletmenin israfla mücadelesinde etkili araçlar sunmaktadır. İsrafın önlenmesi sadece ekonomik bir kazanç değil, aynı zamanda çevresel ve sosyal bir sorumluluktur. Kısa vadeli adımlar, hem işletmenin sürdürülebilirliğine katkı sağlayacak hem de gelecek nesillere daha yaşanabilir bir dünya bırakmanıza yardımcı olacaktır.

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Turkey's Map of Aromatic Plants and Spices

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Abstract

Turkey has a rich potential of aromatic herbs and spices thanks to its geographical location and climate diversity. Under the influence of Mediterranean, Aegean and Black Sea climates, the country is home to diverse ecosystems that allow different plant species to grow. Aromatic plants have an important place in both traditional culinary culture and the modern food industry. Among Turkey's aromatic plants, thyme, mint, sage, chili peppers and basil stand out. The Southeastern Anatolia region in particular stands out with its rich variety of spices. Spices such as pistachio, sumac and isot are the gastronomic identity of this region. The Aegean region is known for herbs and spices used in olive oil dishes, while the humid climate of the Black Sea region allows for the growth of various green herbs. The cultivation of aromatic plants contributes to local economies and supports rural development. However, the sustainable use of these plants is of great importance for maintaining ecosystem balance. Turkey's aromatic herbs and spices map is considered as a critical resource for both the conservation of biodiversity and the preservation of cultural heritage. In this context, supporting local producers and marketing their products play an important role in increasing the economic value of aromatic plants. In conclusion, Turkey's rich diversity of aromatic plants and spices offers gastronomic and economic opportunities at both national and international levels. Utilizing this potential is vital for both agricultural sustainability and the protection of cultural heritage.

Key Words: *Spice, Gastronomy, Aromatic plants*

Türkiye'nin Aromatik Bitki ve Baharat Haritası

Özet

Türkiye, coğrafi konumu ve iklim çeşitliliği sayesinde zengin bir aromatik bitki ve baharat potansiyeline sahiptir. Ülke, Akdeniz, Ege ve Karadeniz iklimlerinin etkisi altında, farklı bitki türlerinin yetişmesine olanak tanıyan çeşitli ekosistemlere ev sahipliği yapmaktadır. Aromatik bitkiler, hem geleneksel mutfak kültüründe hem de modern gıda endüstrisinde önemli bir yere sahiptir. Türkiye'nin aromatik bitkeleri arasında kekik, nane, adaçayı, pul biber ve reyhan gibi türler öne çıkmaktadır. Özellikle Güneydoğu Anadolu Bölgesi, zengin baharat çeşitliliği ile dikkat çekmektedir. Antep fıstığı, sumak ve isot gibi baharatlar, bu bölgenin gastronomik kimliğini oluşturmaktadır. Ege Bölgesi ise zeytinyağlı yemeklerde kullanılan otlar ve baharatlarla tanınırken, Karadeniz Bölgesi'nin nemli iklimi, çeşitli yeşil otların yetişmesine olanak sağlamaktadır. Aromatik bitkilerin tarımı, yerel ekonomilere katkı sağlamakta ve kırsal kalkınmayı desteklemektedir. Bununla birlikte, bu bitkilerin sürdürülebilir bir şekilde kullanımı, ekosistem dengesinin korunması açısından büyük önem taşımaktadır. Türkiye'nin aromatik bitki ve baharat haritası, hem biyolojik çeşitliliğin korunması hem de kültürel mirasın yaşatılması açısından kritik bir kaynak olarak değerlendirilmektedir. Bu bağlamda, yerel üreticilerin desteklenmesi ve ürünlerin pazarlanması, aromatik bitkilerin ekonomik değerinin artırılmasında önemli bir rol oynamaktadır. Sonuç olarak, Türkiye'nin zengin aromatik bitki ve baharat çeşitliliği, hem ulusal hem de uluslararası düzeyde gastronomik ve ekonomik fırsatlar sunmaktadır. Bu potansiyelin değerlendirilmesi, hem tarımsal sürdürülebilirlik hem de kültürel mirasın korunması açısından hayati öneme sahiptir.

Anahtar Kelimeler: *Baharat, Gastronomi, Aromatik bitki*

Giriş

Türkiye, zengin biyoçeşitliliği ve coğrafi konumu sayesinde aromatik bitki ve baharatlar açısından büyük bir potansiyele sahiptir. Bu sunum, Türkiye'nin dört bir yanındaki aromatik bitki ve baharatların haritasını çıkarmayı amaçlamaktadır. Aromatik bitkiler ve baharatlar, hem ekonomik hem de kültürel açıdan büyük öneme sahiptir. Türk mutfağının vazgeçilmez unsurları olmalarının yanı sıra, geleneksel tıpta, kozmetik sektöründe ve aromaterapide de yaygın olarak kullanılmaktadırlar.

Türkiye'nin Coğrafi Avantajları

Türkiye'de birbirinden değerli ve farklı çeşitlerde baharat ve aromatik bitki üretiliyor olmasının başında ülkenin coğrafi avantajları yer almaktadır. İklim çeşitliliği, konumu ve endemik türleri ülkenin coğrafi avantajları arasında yer almaktadır.

Türkiye'nin farklı iklim bölgelerine sahip olması, zengin bir bitki örtüsünün oluşmasını sağlamıştır. Bu çeşitlilik, farklı aromatik bitki ve baharat türlerinin yetişmesine olanak tanır. Karadeniz'in nemli ikliminden Akdeniz'in sıcak iklimine kadar farklı koşullar, çeşitli bitki türlerinin yetişmesi için uygun ortamlar sunar.

Anadolu, tarih boyunca farklı kültürlerin kesişim noktası olmuştur. Baharat Yolu üzerinde bulunması, Türkiye'nin baharat ticaretinde önemli bir rol oynamasına katkıda bulunmuştur. Bu tarihi bağlantılar, Türk mutfağının ve kültürünün zenginleşmesine de büyük ölçüde katkı sağlamıştır.

Türkiye, birçok endemik bitki türüne ev sahipliği yapmaktadır. Bu türler, yalnızca Türkiye'ye özgü olup, ülkenin biyoçeşitliliğinin önemli bir parçasını oluşturur. Yerel çeşitlilik de Türkiye'nin aromatik bitki ve baharat potansiyelini artırmaktadır.

Bölgeler Düzeyinde Aromatik Bitki ve Baharatlar

- Akdeniz Bölgesi

Defne: Türkiye'deki defne üretiminin %80'i Akdeniz Bölgesi'nde gerçekleştirilmektedir. Defne, hem mutfakta hem de geleneksel tıpta yaygın olarak kullanılan bir bitkidir. Özellikle Akdeniz mutfağının vazgeçilmezlerinden biridir.

Mersin: Mersin bitkisinin doğal yetişme alanları bu bölgede bulunmaktadır. Mersin, hem yaprakları hem de meyveleriyle çeşitli kullanım alanlarına sahiptir. Özellikle parfüm ve kozmetik sanayisinde tercih edilen bir bitkidir.

Kekik: Akdeniz Bölgesi, farklı kekik türlerine ev sahipliği yapmaktadır. Dağ kekiği, İzmir kekiği gibi çeşitler, bölgenin zengin bitki örtüsünün bir parçasıdır. Kekik, hem baharat olarak hem de şifalı bitki olarak kullanılmaktadır.

- Ege Bölgesi

Adaçayı: Ege Bölgesi, adaçayı üretimiyle öne çıkar. Adaçayı, şifalı özellikleri nedeniyle hem içecek olarak tüketilir hem de çeşitli sağlık sorunlarına karşı kullanılır. Ayrıca, ihracat potansiyeli yüksek olan bir bitkidir.

Zeytinyağı: Ege Bölgesi'nin zeytinyağları, aromatik bitkilerle zenginleştirilerek farklı lezzetler elde edilir. Zeytinyağı, hem sağlıklı bir yağ kaynağıdır hem de yemeklere eşsiz bir aroma katar.

Rezene: Rezene bitkisinin hem tohumları hem de yaprakları çeşitli kullanım alanlarına sahiptir. Ege Bölgesi'nde rezene, özellikle çay olarak tüketilir ve sindirim sorunlarına iyi geldiğine inanılır.

- Karadeniz Bölgesi

Isırgan Otu: Karadeniz Bölgesi'nde ısırgan otu, hem besin değeri yüksek bir bitki olarak tüketilir hem de geleneksel tıpta çeşitli amaçlarla kullanılır. Özellikle çorba ve börek yapımında tercih edilir.

Mısır Unu: Mısır unu, aromatik bitkilerle birlikte Karadeniz'e özgü mısır ekmeği çeşitlerinin yapımında kullanılır. Bu ekmekler, bölgenin kendine has lezzetlerini yansıtır.

Fındık Yaprağı: Fındık yaprağı, Karadeniz Bölgesi'nde çay olarak tüketilir ve çeşitli faydaları olduğuna inanılır. Fındık yaprağı çayı, özellikle soğuk algınlığına karşı kullanılır.

- Marmara Bölgesi

Lavanta: Marmara Bölgesi'nde lavanta, özellikle kozmetik ve aromaterapi sektöründe yaygın olarak kullanılmaktadır. Lavanta yağı, rahatlatıcı ve sakinleştirici özellikleriyle bilinir.

Nane: Nane, ferahlatıcı özelliği sayesinde Marmara Bölgesi'nde çeşitli kullanım alanlarına sahiptir. Özellikle çaylarda, salatalarda ve tatlılarda tercih edilir.

Biberiye: Biberiye, hem tıbbi hem de mutfak alanında faydaları olan bir bitkidir. Marmara Bölgesi'nde biberiye, özellikle et yemeklerinde ve çaylarda kullanılır.

- İç Anadolu Bölgesi

Kimyon: İç Anadolu Bölgesi'nde kimyon, yemeklerde ve geleneksel tıpta yaygın olarak kullanılan bir baharattır. Özellikle et yemeklerine ve çorbalara lezzet katar.

Anason: Anason, özellikle rakı yapımında kullanılan önemli bir bitkidir. İç Anadolu Bölgesi'nde anason, ayrıca çeşitli tatlılarda ve hamur işlerinde de kullanılır.

Çörek Otu: Çörek otu, şifalı özellikleri nedeniyle İç Anadolu Bölgesi'nde yaygın olarak kullanılan bir bitkidir. Özellikle ekmeklerde, böreklerde ve salatalarda tercih edilir.

- Güney Doğu Anadolu Bölgesi

Pul Biber: Güneydoğu Anadolu Bölgesi, baharatlar konusunda oldukça zengindir. Pul biber, farklı acılık derecelerine sahip çeşitleriyle bölgenin en önemli baharatlarından biridir.

Sumak: Sumak, ekşi tadıyla yemeklere farklı bir lezzet katar.

Mahlep: Mahlep ise tatlılarda ve pastalarda yaygın olarak kullanılır ve kendine özgü bir aroma verir. Bölgenin mutfak kültürü, bu baharatlarla zenginleşmiştir.

- Doğu Anadolu Bölgesi: Doğu Anadolu Bölgesi'nin sert iklimi, bazı özel aromatik bitki türlerinin yetişmesine olanak sağlar. Dağ reyhanı, yüksek rakımlı bölgelerde yetişen ve kendine özgü aroması olan bir bitkidir. Yabani nane, bölgede hem yemeklerde hem de çaylarda yaygın olarak kullanılır. Keven otu ise geleneksel tıpta çeşitli amaçlarla kullanılan bir bitkidir. Bu bitkiler, bölgenin doğal zenginliklerini yansıtır.

Dağ Reyhanı: Yüksek rakımlı bölgelerde yetişen özel bir tür.

Yabani Nane: Yemeklerde ve çaylarda kullanımı.

Keven Otu: Geleneksel tıpta kullanımı.

Türkiye, tarih boyunca Baharat Yolu üzerinde önemli bir роль oynamıştır. Farklı kültürlerin etkileşimi, Türk mutfağının zenginleşmesine katkı sağlamıştır. Baharatlar, geçmişten günümüze Türk mutfağının vazgeçilmez unsurları olmuştur. Baharatların kullanımı, yemeklere farklı lezzetler ve aromalar katarken, aynı zamanda kültürel bir mirasın da yaşatılmasını sağlar.

Türkiye, aromatik bitki ve baharat ihracatında önemli bir potansiyele sahiptir. İhracat yapılan başlıca ülkeler arasında Avrupa Birliği ülkeleri, Amerika Birleşik Devletleri ve Orta Doğu ülkeleri yer almaktadır. İhracatı artırmak için kalite standartlarının yükseltilmesi, yeni pazarlara giriş yapılması ve etkili pazarlama stratejileri geliştirilmesi gerekmektedir.

Türk mutfağında aromatik bitki ve baharatların kullanımı oldukça yaygındır. Her bölgenin kendine özgü yemeklerinde öne çıkan baharatlar bulunmaktadır. Örneğin, Güneydoğu Anadolu mutfağında pul biber ve isot, Ege mutfağında ise kekik ve defne sıklıkla kullanılır.

Baharatlar, yemeklere sadece lezzet değil, aynı zamanda aroma da katarlar. Doğru baharat kullanımı, yemeklerin tadını zenginleştirir ve unutulmaz bir lezzet deneyimi sunar. Türk mutfağının zenginliği, baharatların doğru ve etkili kullanımıyla sağlanır.

Sonuç

Baharatlar, yemeklere sadece lezzet değil, aynı zamanda aroma da katarlar. Doğru baharat kullanımı, yemeklerin tadını zenginleştirir ve unutulmaz bir lezzet deneyimi sunar. Türk mutfağının zenginliği, baharatların doğru ve etkili kullanımıyla sağlanır. Dünyadaki yeni mutfak trendleri (moleküler gastronomi, füzyon mutfağı vs.) arttıkça, Türkiye'nin aromatik bitki ve baharat zenginliğinin önemi de artmaktadır. Sürdürülebilir tarım uygulamaları, iyi tarım uygulamaları ve planlı üretim ile gelecek nesillere aktarılması gereken bu değerli mirasın korunması gerekmektedir.

ID: 685

Prevalence and antibiotic resistance of *Staphylococcus aureus* isolated from commercial poultry carcasses in Ardabil province, Iran

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Abstract

Poultry especially broiler constitutes a large part of protein production in Iran. Nonetheless, farmers use antibiotics for prevention, treatment, and growth enhancement. The objective of this investigation was to determine antibiotic resistance patterns of *S. aureus* isolated from commercial poultry carcasses in Ardabil province, northwest of Iran. Samples were taken from heart blood and liver's visceral surface of 125 carcasses obtained from 30 flocks (including 27 broiler flocks, 1 laying flocks and 2 breeder flocks) located in different parts of Ardabil province. The isolates of *S. aureus* were determined based on microbiological standard methods. The antibiotic susceptibility test was performed using the Kirby-Bauer disk diffusion method. 98 bacteria isolates were identified from 125 carcasses while no bacteria were found in 34 carcasses. Out of 98 isolates, 8 (8.16%) isolates were detected as Staphylococcus aureus. The S. aureus isolates showed resistance to Doxycycline (100 %), Ampicillin (87.5%), followed by Methicillin (75.0%), Sulfamethoxazole-trimethoprim (62.5%), Ciprofloxacin (62.5%), Erythromycin (50.0%), Chloramphenicol (37. 5%), Gentamicin (37.5%), Vancomycin (25.0%) and Cefoxitin (12.5%). Our data indicated that antimicrobial resistance of *S. aureus* was in poultry flocks of Ardabil province, northwest of Iran, and that antibiotics, especially tetracycline and ampicillin, to treat in poultry should be used with caution.

Key Words: *Antibiotic resistance, Poultry carcasses, S. aureus, Ardabil province*

Introduction

Staphylococcus aureus is one of the most prevalent opportunistic pathogens and causes invasive and indubitably life-threatening infections (Amoako et al., 2020). In humans, it is the 3rd most common cause of food poisoning (Amoako et al., 2020). Infections caused by *S. aureus* have been reported in different type of meat like raw chicken, turkey, veal, beef, pork, lamb, and rabbit all over the world. *S. aureus* was found to be most prevalent in turkey followed by chicken, veal, pork, and beef 35.3%, 16.0%, 15.2%, 10.7% and 10.6% ,respectively in Netherland (De Boer et al., 2009). While in Germany, its prevalence was reported in 37.2% of samples of poultry food products (Feßler et al., 2011). In the USA, it was detected in 42.1% of poultry samples (Abdalrahman et al., 2015). From Asia, only a few reports are available, and mainly these reports are of livestock-associated *S. aureus* infections (Chuang et al., 2015). S. aureus is the prominent cause of many infections in the chicken like synovitis, osteomyelitis, and cellulitis (Amoako et al., 2020). It is renowned for its ability to develop resistance to antibiotics. In addition to this, antimicrobial resistance is causing financial loss to the poultry industry because poultry birds have developed resistance to antibiotics. Ample use of antibiotics in animal farming is the prime cause of the prevalence of drug resistance among foodborne pathogens mainly in *Salmonella*, *Staphylococcus spp*. and *E. coli* (Amoako et al., 2020; Ali et al., 2017; Vickers, 2017). It is a widely accepted notion that antibiotics provided in the diet generate selective pressure on the microbial flora that in return facilitates the persistence transfer of antimicrobial resistance determinants among bacterial species which leads to the emergence of multi-drug resistant bacteria (Amoako et al., 2020; De Boer et al., 2009; Suleiman et al., 2013).
Many researchers have isolated (MRSA) from poultry because of the excessive use of antibiotics in the poultry sector. Despite the fundamental consequences of AMR in poultry, our knowledge about antibiotic resistance in *S. aureus* in commercial poultry of Iran is rudimentary, ergo comprehensive research is needed. The present study is aimed to determine the prevalence and antibiotic resistance of *S. aureus* isolated from isolated from commercial poultry carcasses in Ardabil province, northwest of Iran.

Materials and Methods

Sample collection

The study was carried out on 125 carcasses obtained from 30 commercial poultry flocks (including 27 broiler flocks, 1 laying flocks and 2 breeder flocks) in different parts of Ardabil province. So that, five carcasses were

randomly selected from each flock and after necropsy, the heart blood and liver's visceral surface were sampled next to the flame. Collected samples were transported to the laboratory for *S. aureus* isolation.

Identification of *S. aureus*

For processing, enrichment of each sample was carried out in buffer peptone water (BPW) and incubated at 37 ° C for 24 h. Mannitol Salt Agar (MSA) was used as a selective and differential medium for the identification of *S. aureus*. For its purification purpose, distinct yellow colonies from MSA were streaked again onto MSA and stored in glycerol stocks. Initial identification was done based on colony morphology. Afterwards, Gram staining and biochemical characterization were carried out for complete identification which included catalase and coagulase tests.

Antibiotic Susceptibility Test

To determine the antibiotic resistance of the isolates against 10 drugs commonly in the veterinary and medical fields was used qualitative disc diffusion method by Kirby Bauer procedure on Mueller-Hinton agar (Merck, Germany) in according with instructions of Clinical Laboratory Standards Institute Guidelines (CLSI) 2018. On this criterion, the organisms were classified as Resistant (R), Intermediate (I) or Susceptible (S).

Antibiotic disks, procured from Padtan Teb Company of Iran, were amoxicillin (10), doxycycline (30), Vancomycin (30), Sulfamethoxazole-trimethoprim (30), gentamicin (10), ciprofloxacin (5), Erythromycin (10 µg), chloramphenicol (30), Cefoxitin (30) and Methicillin (10 µg).

Result

In this study, 98 bacteria isolates were obtained from 125 carcasses while no bacteria were found in 34 carcasses. Out of 98 isolates, 8 (8.16%) isolates were detected as *S. aureus*. The frequency of resistance of *S. aureus* isolates to ten antimicrobial agents is is as follows:

All isolates were resistant to to doxycycline (100 %) and the resistance to the 9 other antibiotics ranged from 87.5 to 12.5 %. In 9 antibiotics, the highest resistance was found against Ampicillin (87.5%), followed by Methicillin (75.0%),Sulfamethoxazole-trimethoprim (62.5%), Ciprofloxacin (62.5%), Erythromycin (50.0%) and the lowest resistance was found in Chloramphenicol (37. 5%), Gentamicin (37.5%), Vancomycin (25.0%) and Cefoxitin (12.5%).

Discussion

Staphylococcosis caused by S. aureus have varying degrees of morbidity and mortality. It has been reported as a leading pathogen in the poultry industry with a 38.5 % average disease prevalence in 21 European countries (Vickers, 2017). Prevalence of *S. aureus* (8.2%) was observed in the current work While Suleiman et al., (2013) and Ali et al., (2017) reported a higher prevalence (52% and 28%, respectively) [6, 8].

In this study, among all the samples of *S. aureus*, 100 %, 62.5 % and 50 % of isolates showed resistance against doxycycline, Sulfamethoxazole-trimethoprim and Erythromycin, respectively and a similar trend was shown by Yin et al., (2010); Agyare et al., (2018). These three antibiotics are most commonly used in poultry husbandry for prophylactic, metaphylactic and therapeutic purposes. Among all of these isolates 75% were resistant to methicillin and a similar trend was shown by Ali et al., (2017). The reason behind the more prevalence of MRSA might be due to the more common use of methicillin and oxacillin for treatment and growth purposes. In this study less resistance by these isolates to Chloramphenicol; Gentamicin, Vancomycin, and Cefoxitin was observed as 37.5%, 37.5% , 25% and 12.5%. The reason behind less resistance of four antibiotics is not being used or very little of common use in the poultry industry of Iran

Conclusion

In this study, from a total of 98 isolates, 8 isolates were identified as *S. aureus*. High resistance was observed against Doxycycline, Ampicillin, Methicillin, Sulfamethoxazole-trimethoprim, Ciprofloxacin and Erythromycin with 100 %, 87.5%, 75.0%, 62.5%%,62.5% and 50.0% respectively. Isolates were the most susceptible to Cefoxitin, Vancomycin , Gentamicin and Chloramphenicol. Among isolates, only 75 % of isolates were found to be MRSA. The development of drug resistance by *S. aureus* is a matter of concern for food safety because this resistance is transferred from animals to humans. Surveillance of an antibiogram of *S. aureus* is essential for one health concept.

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ID: 687

Geospatial Analysis And Quantification Of Bioaccumulated Pollutants In Fresh Milk

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Abstract

Heavy metals are recognized as non-biodegradable and persistent pollutants released into the water bodies from industries, mining, and agricultural runoff. It not only deteriorates the water quality but also pollutes the soil which further affects plant, animal, and human health. Once it enters the environment it is very difficult to remove. It is common practice in developing countries to use untreated wastewater for irrigation purposes due to a limited water resource. Heavy metals present in untreated industrial wastewater intercalate into the soil where they bio-accumulate in the different parts of plants, that are used as a source of food and fodder. Keeping in this view, the present study is designed to quantify the concentration of heavy metals in fresh milk collected from peri-urban areas of Multan, Pakistan. A total of 80 samples including water, soil, plant, and fresh milk were collected from the five different locations in Multan. The three sites were from urban areas (New Multan, Vehari Chowkh, and Samejabad), and the two sites were from peri-urban areas (Tatty pur and Khandar Wala). The collected samples were prepared using the wet digestion method. Atomic absorption spectroscopy was used for the determination of the concentration of lead, chromium, and cadmium in water, soil, Plant, and fresh milk. The result showed that a high concentration of cadmium in milk at New Multan Milk Site 3 (0.11mg/L) and water at Samejabad site 1 (0.118mg/L) which is above the WHO permissible limit for milk (0.0026µg/g) and water (0.005mg/L). The concentration of chromium in milk is at Samejabad Milk site 2 (0.182mg/L), and water at New Multan Water Site 2 (0.235mg/L) is also above the permissible limit of chromium for milk (0.05mg/L) and water (0.1mg/L). The concentration of lead in milk at Samejabad Milk Site 3 (1.982mg/L) and lead in water at Vehari chowk water site 4 (0.38mg/L) is higher than the permissible limit of lead for milk (0.02 mg/kg) and water (0. 05mg/L). Furthermore, the concentration of cadmium and lead is high in plants used as fodder while the concentration of lead in soil is also above the WHO permissible limit. The geospatial analysis i.e., kriging and Inverse Distance weighted were applied to interpolate lead, cadmium, and chromium in water, soil, plant, and fresh milk. The interpolation of data using kriging and Inverse distance weighted showed that water, soil containing lead, plants containing cadmium and lead, milk containing heavy metals were prevalent sources of metal. It might be possible that water is consumed by animals and fodder grown using canal water is the main source of metal bioaccumulation in milk.

Keywords: *Lead: Cadmium: Chromium: Fresh milk*

ID: 688

Farming with the Forest: Agriculture and Conservation Synergy in Ghana's Western Wildlife Corridor

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Abstract

This study explores farmers' role in the conservation of the Western Wildlife Corridor and associated Community Resource Management Areas in Ghana. Through focus group discussions and key informant interviews, it was found that local communities possess a deep understanding of the corridor's ecological, economic, and cultural values. Farmers identified a wide range of ecosystem services, including provisioning (e.g., firewood, fruits, construction materials), regulating (e.g., climate regulation, water purification), cultural (e.g., traditional knowledge, spiritual value), and supporting services (e.g., soil fertility, pollination). This knowledge has positively influenced the widespread acceptance of community-based natural resource management programmes as conservation tools. Despite facing land-use pressures from commercial farming, grazing, logging, and mining, communities demonstrate a strong commitment to conserving the wildlife corridor, motivated by intrinsic, cultural, and heritage values of biodiversity. Farmers' tolerance of wildlife—despite crop raiding and livestock depredation—is underpinned by cultural beliefs, especially in communities where wildlife are totemic animals. However, delayed or absent compensation for wildlife-related losses remains a critical concern that threatens long-term community support for conservation efforts. Conservation initiatives such as the Modified Taungya System (MTS), green firebelts, and capacity-building under national projects have reinforced local participation. The study highlights that the success of community-based conservation projects stems from collaborative governance structures involving local farmers, forestry and wildlife authorities, and NGOs. However, sustaining these gains requires continued investment in conservation-compatible livelihoods and prompt compensation mechanisms. The findings suggest that integrated landscape management, when informed by local knowledge and supported by inclusive conservation policies, can harmonize agricultural production with biodiversity conservation. Future research is recommended to explore land tenure dynamics in the WWC, particularly regarding commercial land acquisition, to inform sustainable land use planning.

Key Words: Farmers, Agriculture, Conservation, Wild Corridors, Ghana

ID: 689

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Key Words: *Farmers, Agriculture, Conservation, Wild Corridors, Ghana*

Introduction

As land-based activities, agriculture and wildlife conservation are increasingly becoming conflicting land use enterprises as human population surges (Shackelford et al. 2015; Fischer et al. 2017; Egli et al. 2018). This kind of conflict is not only detrimental to biodiversity conservation worldwide but inimical to economic development, food security and sustainable resource use (Watson et al. 2019). The relationship between agriculture and wildlife conservation is complex and multifaceted, particularly in the context of land use. As agriculture expands to meet the growing global demand for food, fiber, and fuel, natural habitats are increasingly converted into farmland, leading to significant shrinkage of wildlife habitats and populations (Ullah & Shabir, 2023; Ortiz et al., 2021). Agricultural activities influence land use patterns, affecting habitat availability, connectivity, and ecosystem health. However, agriculture also has the potential to support wildlife conservation through sustainable and integrated land management practices (Rehman et al., 2022; Williams et al., 2021; Kremsa, 2021).

Recent studies indicate that the main driver of land use and land cover change in Africa is change in agricultural practices through reduction in fallow duration and expansion of commercial agriculture to meet the ever-increasing food demand (Assede et al., 2023; Mala et al., 2020; Gondwe et al., 2019). The consequences of these changes include the loss of vegetation cover, soil erosion, and reduction of agricultural yields in some areas in the continent (Assede et al., 2023). According to Ortiz et al. (2021), shifts in forest cover in Africa could be linked to poverty levels of the population and the need for cultivated land, particularly with the introduction of marked-oriented agriculture systems.

Denudation of Ghana's forest cover has been massive in the last three decades with protected forest reserves suffering average annual deforestation rates of 0.7%, 0.5%, 0.4%, and 0.6% for the periods 1990–2000, 2000–

2005, 2005–2010 and 2010–2015, respectively (FOA, 2015). This process diminishes biodiversity and disrupts ecosystems, making it challenging for both wildlife and cultivated crops to thrive. Forest resources contribute more than one-third (38%) of the income of Ghana's forest-dependent rural population and about 6% of annual Gross Domestic Product of the country (Acheampong et al., 2019; Adjei et al., 2014). With the support of government policies, commercial agriculture is thriving steadily in Ghana and more land is being converted into farms. This makes it difficult to make new cases for the creation of protected areas in the country. The decline of the resource will impact on the livelihoods of those who depend directly on the forest and the economy of the country. If the current rate of deforestation persists, Ghana's forests could completely disappear in two and a half decades time (Boafo, 2013).

To restore degraded forest reserves (protected areas), farmers are allowed to cultivate food crops in affected reserves. This is done under an arrangement known as modified taungya system (MTS). The MTS is an agroforestry system in which during the initial three years of cultivation, farmers are allowed to grow food crops in the allies of planted tree seedlings. The farmers tend both the trees and food crops until the trees form a closed canopy and then they stop growing food crops. However, the farmers continue to tend the trees until they mature. This makes arable land available to landless farmers, but it reduces biodiversity by clearing indigenous species and planting only single economic species in the space (Acheampong et al., 2016).

Another means to curb deforestation is to find an effective way to balance agriculture and biodiversity conservation to achieve conservation goals and agricultural outcomes. This will involve identifying and reforming farming methods that involve total vegetation clearance in favour of single crop cultivation and excessive use of agrochemicals (Dudley et al., 2017; Baudron & Giller, 2014).

Although most rural households keep some sort of livestock, livestock farming is adjunct to crop farming in Ghana. In the Savannah zones, cattle, Sheep, goats and poultry are kept by many households as social security and only sold during household emergencies (Aketemah, 2018). Livestock farming, particularly cattle, has become commercial and widespread in recent times in the savanna agroecological zone. Apart from cattle owned by local farmers, nomads come into northern Ghana from the Sahelian countries such as Niger and Mali to look for better grazing areas, water sources or to sell some animals at international markets (Boesen & Marfaing, 2014; Azarya, 2001). The increasing number of animals creates a new wave of environmental degradation through overgrazing and pollution of water sources for human consumption. Herder-farmer conflicts are also becoming a major security threat as livestock numbers increase. In places where there are forest reserves or wildlife corridors, the herdsmen concentrate grazing (or even settle) in those protected areas to avoid trouble with farmers (Agana et al., 2018). This practice degrades the protected areas and causes biodiversity loss.

The Western Wildlife Corridor (WWC) is part of the greater Mole Landscape linking the Mole National Park in Ghana and the Nazinga Game Ranch in Burkina Faso. The corridor is part of the northern Ghana elephant range, which has the eastern corridor to the east at the border with Togo, and the Nandom range at the extreme north-west of Ghana (Wildlife Division 2000; Blanc et al. 2003). The corridor since its creation has been extended westward to include areas between the Mole National Park and the Gbele Resource Reserve (Majam et al., 2017). It encompasses the sub-watersheds of the main tributaries of the Sissili and Kulpawn Rivers that flow into northern Ghana from Burkina Faso. The corridor contains several forest reserves including Sissili North, Chiana Hills, Sissili Central, Bepona, Gia, Fumbisi, Ghira, Tumu, Mawbia, Ambalara, Kulpawn Headwaters, and Kulpawn Tributaries Forest Reserves. Wildlife protected areas in the corridor are Gbele Resource Reserve and Mole National Park. The Corridor also encloses several hill ranges - the Minjali, Pudo and Chiana hills as well as sacred groves of religious significance that are protected by cultural and traditional norms (Majam et al., 2017). The WWC covers an area of about 3,713km^2 and the distance along the length from Mole National Park to Nazinga Game Ranch is about 143 km. The corridor engulfs over one hundred communities which are mainly farming villages (Majam et al., 2017). The farmers cultivate mainly annual crops including millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*), white beans (*Phaseolus vulgaris*), sesame (*Sesamum indicum*), maize (*Zea mays*), yam (*Dioscorea spp*), cassava (*Manihot esculenta*) and groundnuts (*Arachis hypogaea*). The area is therefore important for both agriculture and biodiversity conservation.

This study was conducted to understand farmers' perception about having to combine agriculture and conservation efforts amidst increasing land hunger and commercial agriculture. The specific objectives include: i) to assess farmers' knowledge of the ecological importance of the wildlife corridor; ii) to assess farmers' acceptance of wildlife as an integral part of their farm space and human-wildlife conflicts; iv) to find out if farmers are still ready to accommodate the wildlife corridor, and v) identify any efforts that may be going on currently to improve the ecological integrity of the wildlife corridor.

Materials and Methods

The study area

The study was conducted in communities within the WWC in northern Ghana (Figure 1). The corridor passes through nine administrative districts in the Upper East, Upper West and North East Regions of Ghana. The human population within the nine districts is 627,180 and the majority of them are farmers. The catchment area of the WWC comprises of wildlife-protected areas, forest reserves and community resource management areas (CREMAs) (Box 1). The reserves and protected areas serve as critical wildlife habitats and provide essential ecosystem goods and services (Majam et al., 2017). The ecosystem services include pollinating agricultural crops, protecting water bodies and creating conducive microclimates for agriculture productivity. The heterogeneous collections of trees meet domestic requirements for firewood and charcoal, construction materials for houses, cattle kraals and fencing of gardens. Dominant tree species in the corridor at naturally vegetated areas include *Terminalia avicennioides, Combretum sp., Anogeissus leiocarpus*, *Vitellaria paradoxa, Daniellia oliveri, Grewia mollis, Gardenia sp., Piliostigma thonningii and Acacia sp.* Economic trees such as *Vitellaria paradoxa, Parkia biglobosa* and *Adansonia digitata* (baobab) are common in cultivated fields (Majam et al., 2017). The shorter shrubs and grasses provide fodder for livestock, which have resulted in high influx of alien Fulani herdsmen into the Corridor (Majam et al., 2017). Some of the most densely vegetated parts of the Corridor are along the channels of Kulpawn and Sissili rivers. However, this riverine vegetation that provides critical habitats for wildlife are under threat (Majam et al., 2017).

Some mammals found in the corridor include Waterbucks (*Kobus ellipsiprymnus defassa*), Bohor reedbuck (*Redunca redunca*), Bushbuck (*Tragelaphus scriptus*), African giant rat (*Cricetomys emini),* stripped Ground Squirrel (*Xerus erythropus*), Nile crocodile (*Crocodylus niloticus*), the monitor lizard (*Varanus sp.),* Oribi (*Ourebia ourebi*), Patas Monkey (*Erythrocebus patas*), Giant Rat (*Cricetomys gambianus*), Togo Hare (*Lepus microtis*), common Genet Cat (*Genetta genetta*), Civet Cat (*Civettictis civetta*), and Grasscutter (*Thryonomys swinderianus*) (Majam et al., 2017). Common bird species within the Corridor include Senegal Parrot (*Poicephalus senegalus*), Cattle Egret (*Bubulcus ibis*), African Green Pigeon (*Treron calvus*), African Grey Hornbill (*Tockus nasutus*), Senegal Coucal (*Centropus senegalensis*), Yellow-Fronted Canary (*Serinus mozambicus*), African Golden Oriole(*Oriolus auratus*), Spotted Fly Catcher (*Muscicapa striata*), Grey-Backed Camaroptera (*Camaroptera brevicaudata*), Yellow-Fronted Tinker Bird (*Pogoniulus chrysoconus* and Grasshopper Buzzard (*Butastur rufipennis)* (Majam et al., 2017).The CREMAs areas and reserves also have socio-economic and cultural functions for the communities (Pienaah et al., 2024).

The WWC falls within the West African semi-arid Guinea savannah belt, which has two main climatic seasons – the rainy season and dry season. The Sissili and Kulpawn Rivers with their many streams and tributaries drain WWC into the White Volta. The geology of the area is that of Middle Voltaic rocks. It consists mainly of Birimian, granite, igneous and metamorphic rock formations some of which are noted for deposits of gold and have consequently attracted illegal mining activities in communities such as Nangurima (Mamprugu Moagduri District), Bassisan and Pido (Sissala East Municipal), Duu, Joanfian and Danyokura (Wa East District) (Majam et al., 2017).

Box 1. **The Community Resource Management Areas (CREMAs) concept**
A CREMA is a geographically defined area that includes one or more communities that have agreed to manage natural resources in a sustainable manner. The CREMA serves as a community-based organization built on existing community decision-making structures including an executive body and a constitution that guides the activities and regulations of the CREMA. A District Assembly bylaw gives legal recognition and backing to the constitution. The community benefits as the CREMA provides a structure which enables collective decision-making for these shared resources while also enabling the community to make collective rules and establish a means by which to enforce these rules. The CREMA also provides a forum whereby external entities are able to access communities.
Source: (Majam et al., 2017)

Data collection methods

Qualitative data collection approaches were used to achieve the study objectives. These include desk study, key informant interviews and focused group discussions.

Desk study: desk study was used to review literature to gather and analyze existing research and publications related to elephant populations, distribution, and movement in Africa and Ghana in particular. We used the African Elephant Database (AED) and Google Scholar web search engine to access scholarly literature, including articles, books, thesis and other relevant sources of literature. Some key phrases used in searches include ‘‘Agriculture and land use’’, ‘‘wildlife habitats’’, ‘‘Agriculture and conservation’’, ‘‘wildlife corridors’’, ‘‘wildlife corridors in Ghana’’, ‘‘human-wildlife conflicts’’, ‘‘conservation in Ghana’’ and ‘‘the CREMA Concept’’

Key informant interviews: key informant interview method was used to gather in-depth information (Taylor & Blake, 2015) and insights from local farmers who possess deep knowledge on wildlife movements and human-wildlife conflicts in the study area. Eight persons, including, two experienced hunters, three local farmers and three

old women were identified in five different communities. All eight persons were older than 60 years. Only people over 50 years were selected because it is believed they might have had the opportunity of witnessing the effective co-existence between humans and wildlife or human-wildlife conflicts in the past. Two senior officials (Assistant Park Manager, MNP and Park Manager, Gbele Resource Reserve) at the Wildlife Division of the Forestry Commission were also interviewed as key informants. Three Forest Guards in charge of forest reserves in the WWC and four Range officers at the Mole National Park and Gbele Game Resource Reserve were interviewed as well.

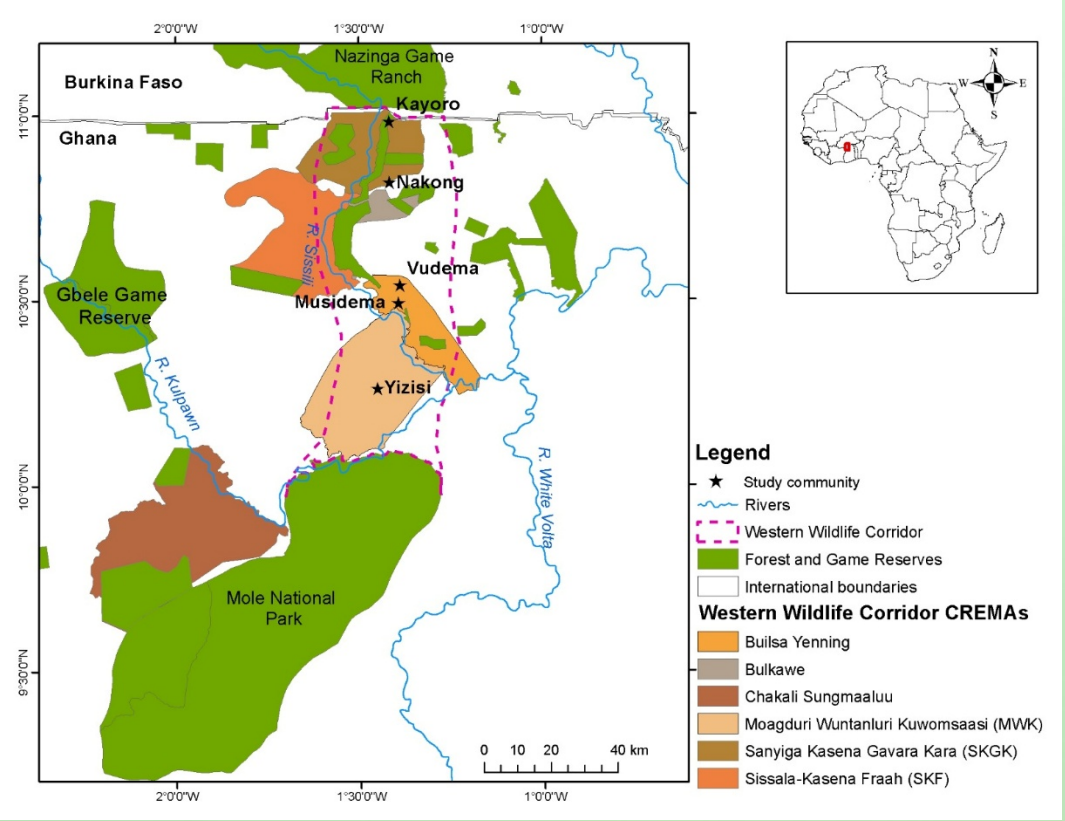


Figure 1. Map of the study area showing study communities

Table 1: Focused group discussion participants

Name of CREMA	Name of community	Number of participants		Community Coordinates	
		Females	Males	Lat. (N)	Long. (W)
Builsa Yenning (BY)	Vudema	5	7	10.541160	-1.388283
Builsa Yenning (BY)	Musidema	6	6	10.493533	-1.392635
Sanyiga Kasena Gavara Kara (SKGK)	Nakong	8	8	10.819513	-1.416515
Sanyiga Kasena Gavara Kara (SKGK)	Kayoro	8	12	10.983318	-1.416515
Chakali Sungmaaluu (CS)	Kulpong	9	11	9.859343	-2.249154
Moagduri Wuntanluri Kuwomsaasi (MWK)	Yizisi	12	9	10.262915	-1.451160

Focused group discussions (FGDs): The FGDs were conducted in six CREMA communities (Figure 1). These communities were purposively (Taylor & Blake, 2015) selected across the length of the WWC to cover its entirety. Participants in the groups comprised of local farmers who also double as community resource management committee (CRMC) members. We deliberately constituted groups with mixed age categories that include elderly people of 50 years or older. The age composition was a measure to ensure that some of the participants have lived long enough to have firsthand information on human-wildlife interaction in the past. Anecdotal statements indicated that wildlife presence in the WWC has been limited in recent years. Table 1 presents the communities and number of participants that took part in the focused group discussions.

Results and Discussion

Farmers' knowledge of the ecosystem services from the WWC and CREMAs

Communities within and around the WWC have demonstrated knowledge of the ecological and socio-economic importance of the WWC. Key informants and focus group discussants listed several ecosystem services including habitat for wildlife, food for human beings, water for all living organisms, fuelwood, wood for construction, cultural identity, indigenous knowledge systems, pollination of flowers, seeds dispersal, climate regulation and soil fertility support and improvement. These services can be categorized into the four main ecosystem services: provisioning, cultural, regulating and supporting services. Table 2 has details of responses from the focus group discussants.

Table 2. farmers' knowledge of ecosystem services

Benefits from WWC and CREMAs	Examples	Category of ecosystem service
Firewood, fruits, grass and rafters for roofing, medicine, fodder	❖ Our wives collect firewood from the CREMAs and the WWC. ❖ We collect edible fruits from shea (*Vitellaria paradoxa*), dawadawa (*Parkia biglobosa*), baobab (*Adansonia digitata*), *Gardenia erubescens* and *Diospyros mespiliformis*. ❖ We harvest thatching grass (*Cymbopogon giganteus*, *Pennisetum purpureum, Pennisetum pedicellatum* Trin) and cut poles (Anogeissus leiocarpus, Pterocarpus erinaceus) for constructing our housing structures.	provision service
The WWC and the CREMAs help to bring rain	❖ The presence of the vegetation in the WWC and the CREMAs provides us with purified water in our area. ❖ The trees in the CREMAs and WWC reduce wind speed to protect our crops from lodging. ❖ The air we breathe here is cleaner than the air at places where there are no trees. ❖ Some insects from trees make our crops produce fruits and seeds. ❖ The weather here is always cooler than the weather in the cities because of the trees we have	Regulating services
For cultural activities	❖ We learn a lot of traditional knowledge on the trees and grasses. ❖ When you walk through the forest your mind becomes relaxed. ❖ Some of the trees and animals represent our items of worship. ❖ We go on communal hunting in the forest.	Cultural services
Brings rain and fertile soil	❖ The plants make our soil fertile for cultivating our crops. ❖ The trees make the rain fall frequently in our area.	Supporting service

This knowledge of ecosystem services may have influenced the acceptance of CREMA establishment in most communities within and around the WWC. This finding is in line with the report of Lamarque et al. (2014) who indicated that farmers in the Central French Alps make environmental/conservation decisions mostly based on their knowledge of ecosystem services. The link between biodiversity loss and food insecurity is a key reminder of farmers about the importance of ecosystem services for effective agricultural productivity (Kpienbaareh et al., 2020). In this study, farmers have also recognized the intrinsic value of wildlife and consider the wild animals as a heritage that must be passed on from one generation to another. A female focus group discussant summarized this: '*The presence of the wild animals in our village lands is important for our community because our forebearers bequeathed them to us and we must also bequeath them to posterity'*. Intrinsic and heritage values of biodiversity

are significant determinants of positive attitudes towards conservation of nature across different classes of society (Abukari & Mwalyosi, 2018; Synman, 2014) and thus contribute to people's acceptance of conservation actions (Roszczynska-Kurasinska et al., 2021; Vucetich et al., 2015). Conservation incentives such as the provision of beehives for apiculture and the provision of cashew seedlings for the cultivation of perennial tree crops in some CREMA communities are very much recognized and appreciated in the studied communities. Success stories from the first beneficiary communities are being used to motivate new and prospective CREMA communities to establish their own CREMAs. However, the communities appealed to wildlife authorities and non-governmental conservation organizations to consider incentives that can benefit both humans and wildlife. For example, the construction of dugouts and dams for irrigation to enable dry season farming. This they indicated can boost their livelihoods through the cultivation of vegetables in the dry season and also serve as watering points for animals, including wildlife.

Farmers' acceptance and tolerance of wildlife albeit problems

In all visited communities, farmers through focused group discussions demonstrated high levels of wildlife tolerance, albeit the challenges they face including crop raiding, wildlife depredation and threat to human life. Figure 2 shows reported incidence of wildlife destruction in the previous five years. The incidence of wildlife destructions is common in communities adjacent to the two main protected areas linked by the WWC – the Mole National Park and the Nazinga Game Reserve. The most affected communities are Kayoro, the closest to the Nazinga Game Reserve and Kulpong, the closest to the Mole National Park. Though farmers are hesitant to retaliate the loss of their crops and livestock to wildlife, they strongly demand conservation authorities to pay them compensation for their loss. The non-payment or inadequacy of compensation for wildlife destruction is the main challenge identified by the communities as emphasized by a FGD participant *'we understand the animals to be animals, as such we can forgive their wrong doing, …but when our fellow human beings in charge of the animals refuse to help us when the animals destroy our crops or kill our livestock, it is frustrating and making it look like the sacrifices we make to protect the wild animals and their habitats are not appreciated'* (FGD; Kayoro; October 2024). None or delay payment of compensation for wildlife destruction is one of the key factors triggering aversion and negative attitudes towards wildlife conservation globally (Gross et al., 2025).

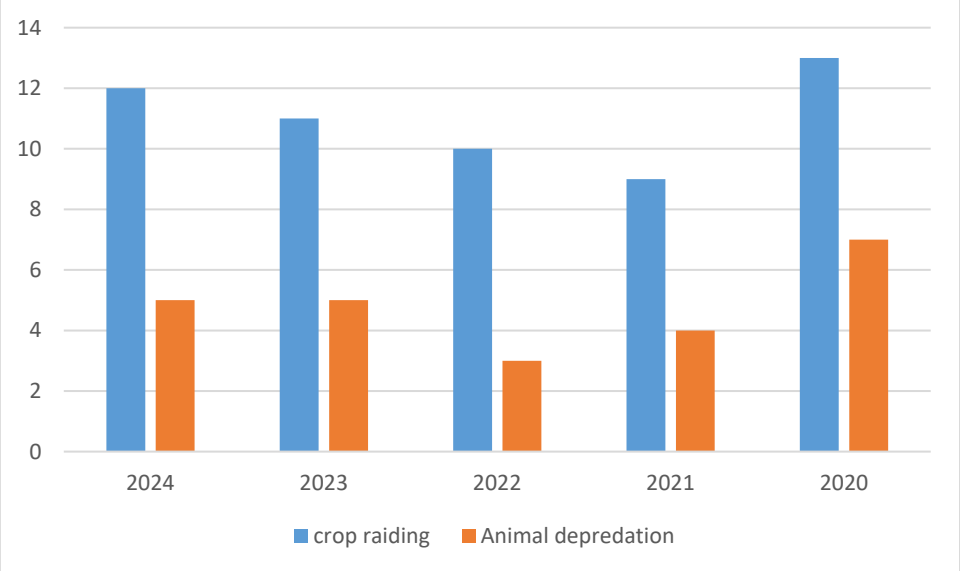


Figure 2. Reported wildlife destruction incidences From 2020 - 2024

Proulx (2024) notes that the cost of wildlife conservation should be borne by all beneficiaries of conservation benefits and not only communities adjacent to protected areas. Compensation for wildlife destruction is therefore one way to distribute the cost of conservation to lessen the burden of victims and present cost-sharing opportunities to other citizens. Crop raiding and livestock depredation are the two main wildlife destructions reported in the in the study area. Crop raiding cases are always more than depredation cases because there are always more herbivorous than carnivorous animals.

Though costly to victims, wildlife destruction does not escalate human-wildlife conflicts in the study area. All key informants and FGD discussants indicated that human-wildlife conflicts have never been a serious concern in the corridor. Though elephants (key crop raiding species) and other wild animals have always been destroying crops on farms, the people have always been tolerant of them and only find ways of driving them away from the farms. These tolerance and positive attitude towards elephants are attributed to the use of the elephant as a totem in many communities in the WWC. Human behavior towards wildlife is often judged on the bases of rational calculus of cost and benefits, ignoring the emotional and cultural aspects of the interaction (Suwannarong et al., 2024; Slagle

& Bruskotter, 2019) that influence behaviour. In this study, the cultural reasons are the key ones engendering positive attitudes and tolerance of wildlife in communities within the WWC. Key informants indicated that there has never been retaliatory killing of elephants for crop raiding. Poachers for the purpose of ivory extraction mostly carried out elephant killings that happened in the corridor. An old hunter however revealed that, even poaching for ivory is no longer lucrative because the current population of elephants in the area carry small tusks, which have low demand. However, it is instructive to note that hunting is a cultural heritage for some clans and individuals in the area. Such hunters will go hunting at all costs just to keep the cultural values alive. This category of hunters also targets the elephant to increase their fame and prestige. According to the traditional hunters' hierarchical arrangement, the highest ranked hunters are the ones that have ever killed an elephant. For this reason, traditional hunters always aspire to kill an elephant to get the highest rank. Farmers who also double as members of CREMA committees are always on the lookout for hunting activities in their vicinities. The CREMA committee members work collaboratively with wildlife authorities and non-governmental conservation organizations to expose wildlife crimes and other illegal activities in the WWC. When they observe illegal activities, CREMA members report to the wildlife authorities or conservation organizations to act.

Should the WWC be maintained?

We posed the question to find out if farmers were comfortable with the WWC's continuous existence because it may appear to be a competing land use activity for them. All participants in the focus group discussions agreed that the WWC should be maintained. They indicated that sustainability and rewilding of the WWC are hinged on the CREMAs in and around the corridor. A key informant at Nakong who was part of the establishment of one of the first CREMAs (SKGK) had this to say: '*at the beginning, we were informed that the main objective of creating the CREMAs in our communities is to help maintain the WWC, and so all the communities that accepted the CREMAs had in deed, agreed to protect the WWC'* (Interview #6; Kong; 2023). However, many key informants and focus group discussants expressed fear about the survival of the WWC and some CREMAs because of current developments. According to discussants and informants, the major threats to the survival of the WWC and CREMAs are expansion of commercial farmlands, expansion of build-up areas, grazing, logging, and mining for minerals such as gold. These activities are creating land hunger in the communities and destroying wildlife habitats. The communities have identified population growth and commercial farming as key underlying factors that drive encroachment into the WWC and some CREMAs. Globally, wildlife habitats are being threatened by the same human activities identified in this study (Padhiary & Kumar, 2024; Taylor-Brown et al., 2019; Scanes, 2018; Wantzen & Mol, 2013). However, the efforts of farmers in the current study to reverse wildlife habitat degradation is similar to those of their counterparts in Naibung'a in northern Kenya, where conservancies are managed through land zoning to improve security of wildlife and livelihoods in same space for farming, grazing and conservation activities (Mureithi et al., 2019). Such community-based initiatives seem to be effective for biodiversity conservation because all stakeholders are involved, and the motivation is based on multiple factors including economic and noneconomic.

Industry players and experts confirmed that the WWC is still relevant as it serves the purpose for which it was created. Forestry and wildlife officers indicated that the WWC is active, but a lot more must be done to provide alternative livelihood activities to communities in and around the corridor. Such livelihood activities must be conservation-compatible and more rewarding than existing livelihoods. Common livelihood activities in the corridor are farming, fuelwood extraction and charcoal production. These land-based livelihood activities put pressure on the resources within the WWC and reduce the quality of wildlife habitats. Farmers in the study area are active in participating in the integrated landscape management to sustain both farming and wildlife corridors and habitats.

Measures taken to safeguard the WWC include proper management of the forest reserves and the creation and maintenance of CREMAs in community lands in and around the corridor. To this end, a WWC management plan was designed mainly to help establish and maintain CREMAs in and around the WWC from 2017 to 2021. The goal was to get the CREMAs to become self-sustaining after their establishment. The Wildlife Division of the FC was largely the technical advisory agency for the implementation of the management plan. The goal of the management plan is largely achieved because six CREMAs are fully established and running. Eight more CREMAs have been inaugurated and are developing at various stages in and around the WWC under the auspices of the Upper West Regional office of the Forestry Commission. At the southern end of the corridor, the Mole National Park is also spearheading the establishment of five new CREMAs to secure a buffer zone around the park and enhance the integrity of the WWC.

Approaches to improve the agri-conservation landscape status of the WWC

Conservation interventions that aim to protect wildlife and their habitats in the corridor and enhance agriculture are often embedded in broader projects being implemented in northern Ghana. On-going projects at the time of this report included the Ghana Landscape Restoration and Small-Scale Mining Project (GLRSSMP) and the Ghana Shea Landscape Emission Reductions project (GSLERP). Under the GLRSSMP, the Forestry Commission (FC) through its Forest Services Division (FSD) undertook green firebreak establishment around forest reserves to prevent or minimize wildfires in the reserves and farms. Local farmers are key participants in this project where

they are taught to plant trees to create green fire belts to protect forest reserves and their farmlands from wildfire. Farmers in Ghana are already conscious about the dangers of wildfires and have over the years adopted indigenous wildfire management regimes for different agroecological zones (Appiah et al., 2010). The green firebelt initiative was therefore an improvement in their capacity to manage wildfire. The findings are also in line with Pinzón et al. (2025) who acknowledged the pivotal role farmers play in the prevention and control of wildfires in California. To ensure sustainability in the management of wildfires among farmers, the FSD also carried out wildfire prevention education, targeting the farmers in communities within the corridor. All these activities aimed at improving wildlife habitats and crop farms in forest reserves and off-reserve areas, respectively. Under the GSLERP, the FSD supported farmers to reforest degraded forest reserves through the modified taungya system (MTS). Taungya is an agroforestry system that combines a stand of woody species and agricultural crops during the early years of plantation development to improve food production and reforestation of degraded areas (Acheampong et al., 2016). The MTS is an improvement of the taungya system to ensure that farmers and other local stakeholders benefit from the proceeds made from harvested timber trees by the state institution in charge of forest resources – the FC (Acheampong et al., 2016). The Wildlife Division (WD) of the FC also received support from the GLRSSMP to strengthen existing CREMAs and create new ones. Through this support, eleven new CREMAs were being established in addition to the existing eight CREMAs at the time this report was made. It is widely recognized that community-based natural resources management approaches like the CREMA in Ghana are designed to empower local communities and make them conscious of their ownership rights of the resources in their vicinity (Heffernan, 2022; Fabricius, 2013; Gruber, 2010; Fabricius & Collins, 2007)

Conservation efforts in maintaining the WWC have largely been successful in both forest reserves and off-reserve areas due to the buy-in of local farmers. According to FSD officials, the forest reserves are in good shape and more farming communities continue to accept the CREMA concept and create CREMAs in their lands. However, a major challenge is the expansion of commercial farmlands in and around the corridor. Grazing, charcoal production and logging are other important activities threatening the ecological integrity of the WWC.

Conclusion

The study has examined the participation of local farmers in an integrated landscape management approach to enhance agriculture and wildlife conservation in same spaces. The results suggest that with the right approach and strategies, seemingly conflicting land use activities such as crop farming and conservation can be married effectively. Underlying cultural values and knowledge of ecosystem services are significant factors that can engender positive attitudes and exude behaviours from farmers that favour conservation. It will therefore be useful to precede community-based conservation interventions with some community education and awarenesss campaigns on all the ecosystem services. This may draw the target audience's attention to the noneconomic services such as supporting, cultural and regulating services, and may secure their buy-in into proposed interventions. Collaboration between various stakeholders in different institutions at the national and local levels is essential to secure genuine participation of local communities. The effective collaboration between the various divisions of the Forestry Commission and the local farmers ensures the successful creation and management of CREMAs in many communities. The local farmers who also double as CREMA executives agreed to participate in protecting the WWC due to the trust established between them and the wildlife authorities. However, it is important to note that financing of various direct and indirect conservation projects in the WWC must be continued since this supports the creation and maintenance of the CREMAs established at different places. It will also be useful to consider the prompt payment of compensation to farmers when they fall victim to wildlife depredation and crop raiding. This will strengthen the support of farmers for the conservation of the WWC and CREMAs. Further studies are needed in the WWC to establish land tenure systems and land transactions to understand how commercial farmers and other investors are able to get large parcels of land for their business activities.

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Determination of the Effectiveness of Microbial Inoculants in Improving the Quality of Sorghum bicolor X Sorghum Sudanese Silage

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Abstract

This study was conducted to determine the effects of adding five different commercial inoculants to Sorghum BicolorXSorghum Sudanese silage on silage quality, microbial development, and aerobic stability. The study consisted of a control group (C) and five inoculant groups (SSSILD, SSSILAP, SSLAC, SSSILAL, SSMIC), prepared in 2 kg vacuum-sealed packages with eight replicates. The prepared silage samples were subjected to fermentation under laboratory conditions, and physical, chemical, microbiological, and aerobic stability analyses were performed after 90 days. Chemical analyses revealed that inoculant addition significantly reduced the pH levels of the silages (P<0.01), with the lowest pH value (4.55±0.00) observed in SSSILAP. The highest crude protein content (10.20±0.00%) was found in SSMIC, while the highest water-soluble carbohydrate (WSC) value (16.15°Brix) was recorded in Control group. Although no statistical differences were observed in color parameters among the groups, inoculant applications positively influenced color stability in terms of ΔE* and hue (h) values (P>0.05). Microbiological analyses showed the highest lactic acid bacteria population (11.00 log5 cfu/g) in SSMIC, with the lowest yeast and mold development. This supports the positive effect of inoculants on aerobic stability. Regarding nutritional value parameters, SSSILAL exhibited the highest digestible dry matter (60.16%), SSMIC had the highest total digestible nutrients (59.02%), Control, SSSILAP and SSMIC showed the highest metabolic energy (2.13 Mcal/kg), and SSSILAP and SSMIC had the highest net energy for lactation (NEL: 1.41 Mcal/kg). In conclusion, inoculant applications significantly improved silage quality, enhanced fermentation efficiency by lowering pH levels, suppressed yeast and mold formation, and improved aerobic stability. SSSILAL and SSMIC outperformed the others, particularly in terms of chemical composition, energy value, and microbiological quality.

Key Words: *Sorghum Bicolor X Sorghum Sudanese Plant, Silage Quality, Microbial Inoculant, Fermentation, Aerobic Stability, Lactic Acid Bacteria, Color Stability, Energy Value, Feed Quality*

Introduction

Silage is an effective preservation method that allows forage crops to be stored for extended periods through fermentation under anaerobic conditions and is used as a fundamental feed source in animal husbandry. High-quality silage production increases agricultural efficiency by reducing animal feeding costs and contributes to environmental sustainability (McDonald et al., 1991). Sorghum bicolor X Sorghum sudanese hybrids are increasingly utilized for silage due to their high biomass yield, drought tolerance, and adaptability to diverse climates (Bean et al., 2013). These hybrids are particularly valued for their ability to produce substantial dry matter yields under water-limited conditions, making them a viable alternative to traditional silage crops like maize in arid and semi-arid regions (Getachew et al., 2016). Studies have shown that Sorghum bicolor X Sorghum sudanese hybrids exhibit favorable nutritional profiles for silage, with moderate crude protein content and high digestible dry matter, enhancing their suitability for ruminant diets (Sánchez-Duarte et al., 2019). For instance, research by Marsalis et al. (2010) demonstrated that these hybrids, when harvested at the soft dough stage, achieve optimal fermentable carbohydrate levels, improving silage quality and aerobic stability. However, their high fiber content and variable carbohydrate levels can complicate fermentation, necessitating the use of microbial inoculants to enhance silage quality (Kung et al., 2003). Lactic acid bacteria (LAB) produce lactic acid by utilizing easily fermentable carbohydrates in plant material, lowering the silage pH, reducing nutrient losses, and inhibiting the growth of undesirable microorganisms (e.g., molds and yeasts) (Kung et al., 2003). Homofermentative bacteria (e.g., Lactobacillus plantarum, Pediococcus acidilactici) enhance aerobic stability through rapid acid production, while heterofermentative bacteria (e.g., *Lactobacillus buchneri*) are effective in preventing aerobic spoilage (Filya, 2004; Muck, 2010). Enzyme-containing inoculants (e.g., cellulase, xylanase) break down plant cell walls, providing more fermentable substrates for LAB and increasing silage digestibility (Özduven et al., 2017). Inoculants combining LAB and enzymes have been reported to reduce NDF and ADF contents and improve organic matter digestibility (Özduven et al., 2017). Similarly, Özduven et al. (2009) reported that LAB inoculants improved fermentation parameters and aerobic stability in corn silage. This study aims to investigate the effects

of different microbial inoculants (SSSILD, SSSILAP, SSLAC, SSSILAL, SSMIC) on the physical, chemical, microbiological, and aerobic stability properties of Sorghum bicolor x Sorghum sudanese silage, optimizing silage quality and nutritional value. The study seeks to contribute to the more effective use of alternative crops like Sorghum bicolor X Sorghum sudanese in sustainable livestock systems.

Materials and Methods

In this study, Sorghum-Sudan Grass Hybrid (Sorghum Bicolor X Sorghum Sudanese) harvested from the research field of Kırşehir Ahi Evran University's Department of Field Crops (Latitude: 39.1286°N, Longitude: 34.1078°E) was used as the primary silage material. The Sorghum Bicolor X Sorghum Sudanese was harvested at the dough stage, chopped to approximately 2.0 cm using a silage machine, and 1000 g of plant material was placed into 2 kg plastic bags. Control group (Control-SS) and five inoculant groups Sorghum Bicolor X Sorghum Sudanese+*Lactobacillus plantarum*, *Enterococcus faecium* bacteria and cellulase, pentosanase, amylase enzymes (SILAID, Global Nutritech Biotechnology LLC, USA), Sorghum Bicolor x Sorghum Sudanese+*L.plantarum, Pediococcus acidilactici, P. pentosaceus, Propionibacteria acidipropionici* and xylanase, β-glucanase enzymes (SILAP Timac Agro, USA), Sorghum Bicolor X Sorghum Sudanese+*Lactobacillus plantarum* only (LAC, Centro Sperimentale Del Latte, Italy), Sorghum Bicolor X Sorghum Sudanese+*L. plantarum, P. acidilactici, P. pentosaceus, P. acidipropionici* and xylanase, β-glucanase, cellulase, amylase enzymes (SILAL, Alltech, UK), Sorghum Bicolor X Sorghum Sudanese+*Lactobacillus brevis, Enterococcus faecium, Bacillus subtilis, Pediococcus acidilactici* and alpha–amylase (*A. oryzae*), cellulase, hemicellulase (*A. niger*) enzymes (MIC, Cuprem®, USA) were treated with inoculants at a concentration of 1×10^5 cfu/g, sprayed homogeneously onto the fresh material After inoculation, the air inside the bags was vacuumed using a vacuum device (Packtech PT-VKM-CPRO). Following vacuum sealing, a total of 30 silage samples (eight replicates per group) were incubated in laboratory conditions at 18.5±2°C in a dark environment for 90 days. At the end of the fermentation process, eight parallel samples from each group were taken, and physical, chemical, microbiological, and statistical analyses were conducted. Dry matter (DM), crude protein (CP), and ash contents of silage samples were analyzed according to AOAC (1998) methods. Organic matter (OM) content was calculated using the formula [%OM = 100 - %ash]. Acid detergent fiber (ADF) and neutral detergent fiber (NDF) analyses were performed following the methods described by Van Soest et al. (1991), using amylase and sodium sulfite, with results expressed including residual ash. Additionally, NDF and ADF contents were corrected for residual ash and reported as NDFom and ADFom, respectively. Hemicellulose content was calculated as [Hemicellulose = NDF - ADF] as defined by Van Soest et al. (1991). Ether extract (EE) content was determined using the ANKOM XT15 Extraction System based on AOCS (2005) protocols. The pH values of silages were measured following Chen et al. (1994), and total soluble solids (TSM) contents were measured according to Singh et al. (2020). Total digestible nutrients (TDN), digestible crude protein (DCP), and metabolizable energy values were calculated using formulas reported by Filik (2020). Color measurements of silages were conducted using a Konica-Minolta CR-410 colorimeter after opening the silage packages, recording L*, a*, and b* values from three different regions of each sample. Chroma (C*, saturation index) and hue angle (h°) were calculated from a* and b* values following AMSA (2012) methods. Lactic acid bacteria, yeast, and mold counts in silage samples were determined using the method described by Seale et al. (1990). Carbon dioxide (CO_2) and pH values on the fifth day after opening the silage packages were measured according to the procedure reported by Ashbell et al. (1991). Relative feed value (RFV) and relative forage quality (RFQ) of silages were calculated using formulas reported by Kılıç and Abdiwali (2016) and Filik (2020). These analyses were conducted at the Animal Biotechnology Laboratory and the Enzyme and Microbial Biotechnology Laboratory of Kırşehir Ahi Evran University's Faculty of Agriculture, Department of Agricultural Biotechnology. Statistical analyses were performed using the SAS (2001) statistical package program. The General Linear Model (PROC GLM) procedure was applied based on a randomized complete block design, and linear relationships between experimental groups were evaluated using orthogonal polynomial contrast analysis. Differences between groups were determined using Duncan's Multiple Comparison Test (Genç & Soysal, 2018).

Results and Discussion

SSSILD had the highest DM content (941.00 g/kg), while SSMIC showed the lowest value (937.15 g/kg). The differences were significant ($p=0.0060$). No significant difference was found in OM and ash ratios ($p=0.1404$), indicating that the mineral content of the silages was similar. SSMIC had the highest CP (10.20%), while SSSILD showed the lowest value (8.87%). There were significant differences in terms of protein content ($p=0.0002$). SSMIC had the highest EE (4.95%), while SSSILAL showed the lowest value (3.86%) ($p<0.0001$). SSSILD has the highest CF (28.91%), ADF (38.74%) and NDF (65.82%) values, indicating higher fiber content. SSSILAL has the lowest ADF (36.90%) and ADFom (29.55%) values, indicating lower lignification and better digestibility. Square and cubic effects for CP, EE, ADF and NDF are significant ($p<0.05$), indicating that the effects of additives on nutrient content are not linear (Table 1). Fiber content (ADF, NDF) in the document aligns with Öten et al. (2024), where ADF ranged from 30.74–35% and NDF from 57.86–62%. The document's SSSILD (ADF: 38.74%, NDF: 65.82%) is higher, indicating lower digestibility, while SSSILAL's lower values (ADF: 36.90%, NDF:63.30%) match BMR cultivars' improved digestibility.

Table 1. Nutrient Content of Sorghum bicolor X Sorghum Sudanese silage

Parameters[5]		DM[1-4]	OM[2]	Ash[2]	CP[2]	EE[2]	CF[2]	ADF[2]	ADFom[3]	NDF[2]	NDFom[3]
Control		939.55^{BAC} ±0.15	92.68^{a} ±0.06	7.33^{A} ±0.06	9.97^{A} ±0.05	4.43^{B} ±0.00	28.10^{B} ±0.14	37.44^{C} ±0.02	30.11^{BC} ±0.05	62.94^{B} ±0.44	55.62^{B} ±0.38
SSSILD		941.00^{a} ±0.10	92.46^{A} ±0.00	7.55^{A} ±0.00	8.87^{c} ±0.00	3.94^{c} ±0.02	28.91^{A} ±0.11	38.74^{A} ±0.21	31.20^{A} ±0.21	65.82^{A} ±0.62	58.28^{A} ±0.61
SSSILAP		938.30^{DC} ±0.60	92.59^{A} ±0.09	7.42^{A} ±0.08	10.01^{a} ±0.17	4.51^{b} ±0.02	28.20^{b} ±0.22	38.09^{b} ±0.19	30.67^{bA} ±0.27	63.56^{B} ±0.54	56.14^{B} ±0.63
SSLAC		939.25^{bC} ±0.15	92.43^{A} ±0.01	7.58^{A} ±0.00	9.45^{B} ±0.11	4.37^{b} ±0.08	28.79^{A} ±0.16	38.23^{B} ±0.15	30.66^{BA} ±0.15	63.66^{B} ±0.33	56.09^{B} ±0.33
SSSILAL		940.05^{BA} ±0.55	92.65^{A} ±0.00	7.35^{A} ±0.00	9.27^{b} ±0.01	3.86^{C} ±0.04	27.96^{B} ±0.02	36.90^{d} ±0.03	29.55^{d} ±0.03	63.30^{B} ±0.00	55.95^{B} ±0.00
SSMIC		937.15^{D} ±0.55	92.44^{A} ±0.13	7.57^{A} ±0.14	10.20^{A} ±0.00	4.95^{A} ±0.04	28.43^{BA} ±0.04	37.56^{C} ±0.04	30.00^{DC} ±0.10	62.06^{B} ±0.96	54.50^{B} ±0.82
SED		0.1683	0.0287	0.0287	0.0350	0.0173	0.0551	0.0535	0.0641	0.2300	0.2174
P values		0.0060	0.1404	0.1404	0.0002	<.0001	0.0124	0.0006	0.0029	0.0389	0.0326
Effects ¥	L	0.0987	0.0964	0.0964	0.3380	0.0862	0.0644	0.0257	0.1652	0.9681	0.7711
	Q	0.5665	0.6848	0.6848	0.0200	0.0055	0.4365	0.0045	0.0128	0.0490	0.0436
	C	0.0055	0.0883	0.0883	<.0001	<.0001	0.0035	0.0033	0.0235	0.0246	0.0278

1 g/kg natural material, 2 (%) of dry matter, 3 ADFom=ADF ash, NDFom=NDF ash; 4 DM: In Air Dry Matter (g/kg); OM: Organic Matter (%); Ash (%); CP: Crude Protein (%); EE: Ether Extract (%); CF: Crude Fibre (%); ADF: Acid Detergent Fibre (%) and NDF: Neutral Detergent Fibre (%). a,b,c,d .Means within the same column with no common superscript differ. significantly (P<0.01). ¥ L: linear; Q: quadratic; C: cubic effects. SED: Standard error of the difference between 2 means.

SSSILAL had the highest NFE value (51.56%), while SSMIC showed the lowest value (48.87%) (p<0.0001). SSSILAL had the highest NFC (16.23%), while SSSILD showed the lowest value (13.83%). However, this difference was not statistically significant (p=0.2149). SSSILD had the highest TC (79.65%), while SSMIC showed the lowest value (77.30%) (p=0.0001). Control, SSSILAP and SSMIC had the highest energy values (DE: 2.60 Mcal/kg, ME: 2.13 Mcal/kg), while SSSILD showed the lowest energy values (DE: 2.54 Mcal/kg, ME: 2.08 Mcal/kg). NEL, NEM and NEG values also followed a similar trend. The square and cubic effects on energy values are significant (p<0.05), indicating that the effects of additives on energy content are complex (Table 2). Öten et al. (2024) reported digestible energy (DE) and metabolizable energy (ME) improvements with molasses, with DE values around 2.5–2.7 Mcal/kg, closely matching the document's range (2.54–2.60 Mcal/kg). The document's high-energy silages (Control, SSSILAP, SSMIC) align with these findings.

Table 2. Energy values of Sorghum bicolor X Sorghum Sudanese silage

Parameters[1, 2, 3]		NFE	NFC[1]	TC[1]	DE	ME	NE_L	NE_M	NE_G
Control		50.17^{C} ±0.15	15.35^{BA} ±0.45	78.29^{CB} ±0.01	2.60^{A} ±0.01	2.13^{A} ±0.00	1.32^{A} ±0.00	1.27^{A} ±0.00	0.70^{A} ±0.00
SSSILD		50.74^{b} ±0.08	13.83^{B} ±0.59	79.65^{a} ±0.02	2.54^{c} ±0.00	2.08^{c} ±0.00	1.29^{c} ±0.00	1.23^{c} ±0.00	0.66^{c} ±0.00
SSSILAP		49.87^{c} ±0.07	14.52^{bA} ±0.26	78.07^{C} ±0.28	2.60^{A} ±0.01	2.13^{A} ±0.00	1.33^{A} ±0.01	1.27^{A} ±0.01	0.71^{A} ±0.01
SSLAC		49.82^{c} ±0.14	14.95^{BA} ±0.30	78.61^{B} ±0.02	2.57^{b} ±0.00	2.11^{b} ±0.00	1.31^{b} ±0.01	1.25^{B} ±0.00	0.69^{b} ±0.00
SSSILAL		51.56^{a} ±0.07	16.23^{A} ±0.04	79.52^{A} ±0.05	2.56^{B} ±0.00	2.10^{B} ±0.00	1.30^{B} ±0.00	1.25^{B} ±0.00	0.68^{B} ±0.00
SSMIC		48.87^{D} ±0.13	15.24^{ba} ±1.13	77.30^{D} ±0.17	2.60^{A} ±0.00	2.13^{A} ±0.00	1.33^{A} ±0.00	1.28^{A} ±0.00	0.71^{A} ±0.00
Effects ¥	SED	0.0454	0.2356	0.0554	0.0014	0.0014	0.0011	0.0016	0.0011
	P values	<.0001	0.2149	0.0001	<.0001	0.0004	0.0004	0.0011	0.0001
	L	0.0073	0.8455	0.3471	0.0688	0.3794	0.4680	0.3153	1.0000
	Q	0.0371	0.1413	0.0224	0.0123	0.0123	0.1340	0.0498	0.0134
	C	0.0040	0.3746	0.0002	<.0001	<.0001	<.0001	0.0003	<.0001

[1](%) of dry matter;[2] Data represent the mean of four applications of each treatment; [3] NFE: nitrogen-free extract (g/kg); NFC: non-fibre carbohydrates (g/kg) and TC: total carbohydrates (g/kg), DE: digestible energy (Mcal/kg); ME: Metabolizable energy (ME Mcal/kg), NEL : net energylactation (Mcal/kg), NEM: net energy-maintenance (Mcal/kg), NEG : net energy-gain (Mcal/kg). a,b,c Means within the same column without common superscript are significantly different (P<0.01). ¥ L: linear; Q: quadratic; C: cubic effects. SED: Standard error of the difference between 2 means.

SSSILAL had the highest DDM (60.16%), while SSSILD had the lowest value (58.72%) (p=0.0006). SSMIC had the highest DMI (1.93%), while SSSILD had the lowest value (1.83%) (p=0.0444). SSMIC had the highest TDN (59.02%), while SSSILD had the lowest value (57.61%) (p=0.0003). SSMIC had the highest RFV (89.43) and RFQ (92.81) values, while SSSILD showed the lowest values (RFV: 83.00, RFQ: 85.40). Square and cubic effects were significant for DDM, TDN, RFV and RFQ (p<0.05) (Table 3). Öten et al. (2024) reported RFV values of 63.78–81.53 for Sorghum x Sudan grass hybrids, lower than the document's range (83.00–89.43). The document's SSMIC (RFV: 89.43) exceeds these values, likely due to lower ADF/NDF and higher CP. DDM and DMI values in the document are comparable to high-quality silages reported by Aguiar et al. (2006), where Sudan grass silage matched ruminant nutritional standards.

The control group had the highest temperature (20.28°C), while SSSILD showed the lowest temperature (16.18°C). The temperature differences are statistically significant (p<0.0001). Lower temperature may indicate better preservation of silage. SSSILAP had the lowest pH value (4.55), while the control group showed the highest

pH (4.68). Lower pH means better lactic acid fermentation and silage stability. SSLAC had the highest WSC value (17.40), indicating more fermentable carbohydrates. SSSILAL had the lowest WSC (15.23). SSSILAL has the highest L* (56.33, lighter color) and ΔE (59.77, total color difference) values, which may indicate that the color change is more pronounced. SSSILD has the highest a* (4.08, redness), while b* (yellowishness) and C* (chroma) values are generally similar. Although there are some significant differences in color parameters (e.g. p=0.0341 for h), no major differences are observed overall. Linear (L), quadratic (Q) and cubic (C) effects for temperature and pH are significant (p<0.0001). However, these effects are less pronounced in color parameters (Table 4). A study by Salman and Budak (2015) evaluated Sorghum x Sudan grass hybrids (e.g., Nutri Honey, Aneto) and reported pH values for silages ranging from 4.2 to 4.8, aligning with the document's range (4.55–4.68). The lower pH in SSSILAP (4.55) is consistent with high-quality silage, as pH below 4.6 is optimal for lactic acid fermentation.

Table 3. Forage quality of Sorghum bicolor X Sorghum Sudanese silage

Parameters[1, 2, 3]		DDM	DMI	TDN	RFV	RFQ
Control		59.74^{b} ±0.01	1.91^{a} ±0.02	58.81^{a} ±0.06	88.30^{a} ±0.64	91.16^{ba} ±0.75
SSSILD		58.72^{d} ±0.17	1.83^{b} ±0.02	57.61^{c} ±0.01	83.00^{b} ±1.02	85.40^{c} ±0.83
SSSILAP		59.23^{c} ±0.14	1.89^{a} ±0.01	58.85^{a} ±0.19	86.71^{a} ±0.95	90.36^{ba} ±1.08
SSLAC		59.12^{c} ±0.12	1.89^{a} ±0.01	58.23^{b} ±0.13	86.40^{a} ±0.62	89.24^{b} ±0.66
SSSILAL		60.16^{a} ±0.02	1.90^{a} ±0.00	58.09^{b} ±0.02	88.42^{a} ±0.02	89.54^{ba} ±0.03
SSMIC		59.64^{b} ±0.03	1.93^{a} ±0.03	59.02^{a} ±0.00	89.43^{a} ±1.44	92.81^{a} ±1.44
	SED	0.0422	0.0066	0.0395	0.3646	0.3687
	P values	0.0006	0.0444	0.0003	0.0204	0.0142
Effects ¥	L	0.0268	1.0000	0.2922	0.6369	0.8495
	Q	0.0046	0.0498	0.0259	0.0313	0.0424
	C	0.0035	0.0338	<.0001	0.0171	0.0060

[1] (%) of dry matter; [2] Data represent the mean of four applications of each treatment; [3] DDM: digestible dry matter (%); DMI: dry matter intake (live weight: LW, %); TDN: total digestible nutrients (%); RFV: relative feed value and RFQ: relative forage quality. a,b,c Means within the same column without common superscript are significantly different (P<0.01). ¥ L: linear; Q: quadratic; C: cubic effects. SED: Standard error of the difference between 2 means.

Table 4. Quality and color of Sorghum bicolor X Sorghum Sudanese silage

Parameters[1]		°C±SEM	pH	WSC (°Brix)	*L**	*a**	*b**	*ΔE**	*h*	*C**
Control		20.28^{a} ±0.16	4.68^{a} ±0.02	16.15^{ba} ±0.06	52.02^{bA} ±1.68	2.98^{b} ±0.15	17.91^{A} ±0.69	55.10^{A} ±1.81	80.56^{a} ±0.37	18.16^{A} ±0.70
SSSILD		16.18^{d} ±0.14	4.59^{bc} ±0.01	16.35^{a} ±0.26	49.22^{B} ±1.09	4.08^{A} ±0.38	17.94^{A} ±0.30	52.55^{A} ±1.12	77.22^{b} ±1.04	18.40^{A} ±0.35
SSSILAP		16.58^{c} ±0.09	4.55^{c} ±0.00	16.58^{ba} ±0.19	51.25^{ba} ±2.65	3.90^{Ba} ±0.26	18.51^{a} ±1.02	54.64^{a} ±2.82	78.09^{ba} ±0.54	18.92^{a} ±1.03
SSLAC		17.10^{b} ±0.04	4.59^{bc} ±0.01	17.40^{a} ±0.57	51.72^{ba} ±1.17	3.68^{ba} ±0.40	18.23^{a} ±0.59	54.97^{a} ±1.30	78.64^{ba} ±1.04	18.61^{a} ±0.62
SSSILAL		16.92^{cb} ±0.22	4.66^{a} ±0.01	15.23^{b} ±0.08	56.33^{a} ±3.11	3.22^{Ba} ±0.21	19.71^{A} ±1.06	59.77^{a} ±3.27	80.63^{a} ±0.88	19.97^{a} ±1.04
SSMIC		17.05^{b} ±0.06	4.64^{ba} ±0.03	15.45^{b} ±0.76	53.98^{ba} ±1.99	3.15^{Ba} ±0.26	19.04^{a} ±0.91	57.33^{a} ±2.15	80.54^{a} ±0.96	19.31^{a} ±0.89
SED		0.0544	0.0071	0.1732	0.8508	0.1184	0.3295	0.9054	0.3455	0.3307
P Value		<.0001	0.0003	0.0142	0.2778	0.0780	0.5923	0.3204	0.0341	0.6502
Effects ¥	L	<.0001	0.0008	0.2462	0.9044	0.1546	0.6762	0.8660	0.2130	0.6125
	Q	<.0001	0.0008	0.5439	0.4416	0.0344	0.8511	0.5233	0.0335	0.7348
	C	<.0001	0.5705	0.3891	0.5007	0.3508	0.7032	0.5274	0.2462	0.7644

[1] °C: Celsius degree; WSC: water soluble carbohydrate value (Brix degree 0 - 25°); L: Lightness; a*: Redness; b*: Yellowness; ΔE*: The total color difference; h: hue angle and C*: Chroma or saturation. a,b,c Means within the same column without common superscript are significantly different (p<0.01). ¥ L: linear; Q: quadratic; C: cubic effects. SED: Standard error of the difference between 2 means.*

DM (After Aerobic Stability), SSLAC had the highest DM (55.54%), while SSMIC showed the lowest value (48.91%) (p<0.0001). SSLAC had the lowest pH (4.36), while SSSILD showed the highest value (4.54) (p<0.0001). Low pH is advantageous in terms of aerobic stability. There is no significant difference in CO_2 production (p=0.9669), which may indicate that aerobic degradation was similar in all silages. SSMIC had the highest LAB count (11.00 $Log10^5$ cfu/g) before aerobic stability, while LAB counts were low in other silages (1.00-2.50 $Log10^5$ cfu/g). However, this difference is only marginally significant (p=0.0527). Linear, quadratic and cubic effects for DM and pH are significant (p<0.05). Öten et al. (2024) reported pH values of 3.99–4.5 post-aerobic exposure, aligning with the document's range (4.36–4.54). SSLAC's low pH (4.36) matches high-stability silages enhanced by molasses.

The low pH in SSLAC (4.36) indicates effective preservation, Likely due to high organic acid content (e.g., acetic acid), which inhibits spoilage organisms. This aligns with findings by Kung et al. (2003), who reported that rapid pH decline in silages treated with homofermentative LAB enhances preservation by limiting the growth of yeasts and molds. Similarly, Contreras-Govea et al. (2013) observed that sorghum silages with pH below 4.4, driven by increased lactic and acetic acid production, exhibited superior fermentation quality. The higher pH in SSSILD

(4.54) suggests reduced stability, possibly due to lower acid production or consumption by aerobic microbes, consistent with Muck (2010), who noted that inadequate acid accumulation can lead to secondary fermentation and reduced aerobic stability. The lack of significant CO_2 differences implies that all silages experienced comparable aerobic microbial activity post-exposure, despite differences in pH and DM. This could indicate that CO_2 production is less sensitive to additive effects in this study, as supported by Ashbell et al. (1991), who found that CO_2 levels in silages may not always correlate with microbial inoculant efficacy due to variable aerobic deterioration rates. Weinberg and Muck (1996) further suggest that CO_2 production is influenced by residual fermentable substrates, which may be similar across treatments in this case. LAB Count: SSMIC's high LAB count (11.00 Log10 cfu/g) reflects strong fermentation, likely driven by homofermentative or heterofermentative LAB inoculants. Filya (2004) reported that high LAB populations in inoculated silages enhance lactic acid production, improving fermentation efficiency. However, the low DM (48.91%) in SSMIC suggests that LAB activity may have consumed DM during aerobic exposure, reducing stability, as noted by McAllister et al. (2018), who found that excessive LAB activity in sorghum silages can lead to DM losses under aerobic conditions. Other treatments (e.g., SSLAC) with lower LAB counts maintained higher DM, indicating better aerobic stability, consistent with Contreras-Govea et al. (2013), who emphasized that balanced LAB populations optimize both fermentation and aerobic stability in sorghum silages.

Table 5. Effects of Sorghum bicolor X Sorghum Sudanese silages

Parameters[5]	DM after Aerobic Stability	pH_2	CO_2	Yeast After Aerobic Stability (Log 10^5 Cfu/g)	Lactic Acid Bacteria Before Aerobic Stability (Log10^5 cfu/g)	Lactic Acid Bacteria (Anaerobic) (Log10^5 cfu/g)	Molt After Aerobic Stability
Control	49.36^{cb} ±0.41	4.48^{b} ±0.01	2.20^{a} ±0.31	-	1.00^{B} ±	-	-
SSSILD	49.15^{C} ±0.01	4.54^{a} ±0.01	2.08^{a} ±0.07	-	1.00^{B} ±	-	-
SSSILAP	50.05^{B} ±0.03	4.40^{c} ±0.02	2.08^{a} ±0.07	-	1.50^{B} ±0.50	-	-
SSLAC	55.54^{A} ±0.34	4.36^{d} ±0.00	2.02^{a} ±0.13	-	2.50^{B} ±0.50	-	-
SSSILAL	49.43^{cb} ±0.23	4.48^{b} ±0.01	2.14^{a} ±0.13	-	1.00^{B} ±	-	-
SSMIC	48.91^{c} ±0.08	4.46^{b} ±0.02	2.14^{a} ±0.13	-	11.00^{A} ±2.00	-	-
SED	0.0969	0.0049	0.0458	-	0.7905	-	-
P values	<.0001	<.0001	0.9669	-	0.0527	-	-
Effects ¥ L	<.0001	<.0001	0.4644	-	0.6328	-	-
Q	<.0001	0.0006	0.8447	-	0.8287	-	-
C	0.0042	<.0001	0.8033	-	1.0000	-	-

CO_2: Amount of Carbon Dioxide; pH: After Aerobic Stability pH. Means within the same column without common superscript are significantly different (P<0.01). SED: Standard error of the difference between two means. L: Linear; Q: Quadratic; C: Cubic effects.

Conclusion

The quality of Sorghum bicolor X Sorghum Sudanese silages varies significantly depending on the LAB inoculant applied. Especially SSLAC and SSMIC (homofermantative) groups showed superior performance compared to other groups in terms of silage quality, nutritional values and microbiology. Both high energy content and good feed quality parameters in these groups support the preference of these inoculants in practice. In conclusion, this study shows that different LAB inoculants can significantly improve the properties of Sorghum bicolor X Sorghum Sudanese Silage silages. This can provide important contributions to farmers in terms of reducing feed costs and increasing animal health and performance. Future research should focus on optimizing inoculant combinations, different plant species, and regional climate conditions. Additionally, more comprehensive studies on the long-term effects and economic feasibility of inoculants could support the widespread adoption of this technology at a commercial scale. Such studies will contribute to developing innovative and environmentally friendly solutions in global feed production.

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Industrial Precursors from Agricultural Wastes

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Abstract

Potential copolymers as industrial precursors were developed from *Carica papaya* seeds oil. *Carica papaya* fruits were collected in Ibadan, Nigeria. Seed oils of this fruit were extracted using n-hexane and concentrated. Phenolated *carica- papaya* biopolymer(PCPB) was prepared by polymerizing the oil with phenol through cationic polymerization method. Polyacrylamide(PAA) and Polyacrylonitrile(PAN) were prepared through free radical polymerization technique. The copolymers were prepared by polymerizing PCPB, PAA and PAN to produce PCPB-PAA and PCPB-PAN. They were characterized using FTIR for functional groups modifications, ^{1}H-NMR for changes in chemical environments and Viscometry techniques for mean molecular weight determination.

The oil yield is 32.22%. Iodine value(gI_2/100g) is 99.55±0.38 and 61.98±0.06 for oil and PCPB respectively. FTIR band shifts at 1552.75cm^{-1} confirm C=C stretch of aromatics in PCPB. PAA formation was confirmed with C=O stretch at 1680.00cm^{-1}. Peak at 2250cm^{-1} confirm C≡N of PAN. Peak at 3474.24cm^{-1} confirm N-H stretching vibration of amides that suggest polyester-amide copolymer. C-N bond occurred at 2034.28cm^{-1} to establishe PCPB-PAN copolymer. The ^{1}H-NMR spectra showed peaks at δppm, δ8.11ppm(s, 2H) to confirm aromatics in PCPB. δppm at 7.18 confirmed peptide protons in PAA. δ 7.18(s, 1H) and 6.86(s, 3H) suggest that PAA was grafted to PCPB backbone. δ4.89ppm(q, J = 8.8 Hz, 1H) suggests the presence of substituted nitrile in PCPB-PAN. Both FTIR and ^{1}H-NMR results confirmed formation of new copolymers. The mean molecular weight(g/mol) for PCPB, PCPB-PAA and PCPB-PAN are 7.482x10^9, 1.062x10^{12} and 1.135x 10^{12} respectively to affirm the grafting processes.

The results suggest that ecologically friendly industrial precursors are feasible from Agricultural wastes.

Keywords: *Copolymers, Industrial, Agricultural wastes, polymerization, Carica Papaya*

Introduction

Agricultural activities all over the world generate wastes that are underutilised or not in use at all. In most countries in Africa, these wastes are consistently discarded as there are less available proven technologies to find purposes for them (Nikesh and Prakash 2015; Srikanth et al., 2022). Some of the wastes includes seeds of fruits, peels, rice bran, fruits shells, nuts of fruits like cashew, palm fruit and coconuts and the list is endless. Many of them are allowed to decompose and germinate and others litter the environments(Montero et al., 2011). Among these endless waste seed is *Carica papaya* seeds. Carica papaya fruit is widely produced and consumed on the African continent. This is because most of the countries in Africa operate agro-based economies. Nigeria in particular, Agriculture has been a stable component of the life of people in the various savannahs. *Carica papaya* is an annual crop which means its available every year. It will also be available all through the year round if it is well preserved (Malacridai et al., 2011). The seeds from this fruits are often discarded after the flesh has been consumed since they have limited use. Researchers have however shown that the seed is rich in viable functional groups like esters, vinyl group, carbonyl group, fatty acid group, fatty alcohol and ether groups. These seeds can then be modified under suitable chemical/unit process to obtain viable chemical precursors.

The feedstock used in the various industries like the petrochemicals, pharmauticals, textile, polymer industries and a host of others have gotten their starting materials majorly from petroleum sources(Askarian et al., 2018). These petroleum sources have been found to be finite and hence at a certain time and counts, it may not be available to man anymore. Besides, relying heavily on petroleum has resulted into some environmental nuisances. Plastics from ethane and propene monomers are not biodegradable. They can occupy the land fill sites for years and then lead to alteration in the food chain which can contribute to food scarcity and astronomical prices. One of the problems facing the earth today is the end use of the plastics that have been produced(Gupta and Kashani 2021). Several propositions have been made such as recycling, incineration and sustainable processes with each creating new set of problems. Incineration releases toxic chemicals to the environment like CO and SO_2 (Poudyal and Adhikari, 2021). Recycling releases harmful chemicals such as HCl and H_2S and the sustainable process implies postponing the evil day for a foreseeable future. Relying on petrol for fuel has contributed heavily to the release of excess CO_2 into the environment which had led to sporadic increase in the temperature of the earth(Nair and Vishnudas, 2024). Excess heat can also lead to the denaturation of proteins in the body that can lead to various

degree of sicknesses and major life damages such as infertility, undue death, weakness of the flora and fauna antibodies and blue blood syndrome. Oil spillage, water pollution and poisoning are other problems associated with regions where oil rigs exist. Aquatic species are facing difficulty in breathing ,migration and extinction and quality of water available to homo-sapiens in these regions are low and uneconomical. Wrong government policies and allied by the oil industries contribute further issues around these parts of the countries. Nations in Africa always experiences militancy, bunker, pipe line vanderlization (Thomas 2018).

These problems and similar factors had prepared the chemical industries to think of alternatives to crude oil for feed stock production (Jittin et al., 2021; Afolabi et al., 2020). Among the array of other things such as coal, ammoniacal liquols, bitumen, biomass and others considered, the biomass wastes offers viable alternative. Biomass are all from agricultural sources. To avoid creating problems of sporadic increase in food prices, the non –edible underutilised biomass have been the most viable agricultural wastes that can moderately satisfy the requirement of man in his technological growth and desires without affecting the ecosystem. Among these non-edible underutilised biomass is *carica papaya* seed oil.

Carica papaya L. is grown all over the world and is available to the tone of 100 million metric tons, all over the world annually. Its central cavity contains large quantities of seeds that comprise averagely 15% of the wet weight. *Carica papaya* L. seeds have been used for decades in parts of Asia and South America as a vermifugal agent, folk medicine due to its abortive properties, to enhance good menstrual flow in women and to adulterate black pepper. The availability of the seeds shows that it can be depended upon. The oil yield from literatures shows the oil to be in the range of 30-45% depending on the region to suggest commercial viability. The oil has also been confirmed to be rich in oleic acid up to 70%. This makes the oil to be a viable candidate for addition polymerization reaction (Elahi et al., 2020).

Despite the plethora of literature works on this *carica papaya L.* seed oil. There are sparse literary submissions on its viability as source for producing feedstock for chemical industries. This research therefore probe into the possible use of *Carica papaya* seed oils for production of suitable industrial precursors for chemical industries with the focus on mitigating the problems associated with those from petroleum sources (Blesson et al., 2023; Omotoso and Akinsanoye, 2017). The precursors and materials form them are expected to be biodegradable and photodegradable. The research will also contribute immensely to the available agricultural starting materials for producing environmental friendly industrial chemicals' precursors.

Methodology

Materials

The materials employed for this research work include Pawpaw seeds (*Carica papaya),* phenol, acrylamide, acrylonitrile, toluene, perchloric acid, distilled water, hydroquinone, Fenton's reagent (Hydrogen peroxide+ Ferric ammonium sulphate in 1:1), ethanol.

Methods

Sample collection and sampling methods

Pawpaw seed sample preparation

Pawpaw seeds were obtained largely from Ibadan in Oyo state, Nigeria. The seeds were obtained from the fruits by mechanical means. The seed samples were dried and the moisture contents were determined. The seeds (dark brown) were grounded with a blender and were prepared for extraction.

Extraction and phenolation of oil

The oil was extracted from the seeds using hot extraction technique and concentrated. Physicochemical parameters were determined. The extracted oil was phenolated with phenol through grafting technique. This was done by mixing melted phenol and the triglyceride in ratio 1:3 using a batch reactor in the presence of nitrogen gas to provide inert environment. The mixture was thoroughly homogenised for few minutes. The reaction mixture (1% of the combination) was combined with perchloric acid ($HClO_4$) as catalyst. They were allowed to proceed for six hours at 90^0C in an inert atmosphere created by utilizing nitrogen gas. After the reaction materials were polymerized for six hours, they became dark-brown. The reaction products were observed to have grown very viscous after four hours of polymerization. The final product was a dark-brown viscous liquid. The process was stopped after six hours. They were allowed for 20 minutes to cool. To ensure that the unreacted phenol, unreacted triglycerides, and acid catalysts were eliminated, powdered $Ca(OH)_2$ was added to the reaction mass. To get rid of any remaining impurities, ethanol was used to wash the finished product. The resultant phenolated product was dried for 48 hours on sodium sulfate. The product obtained were stored in tightly fitting containers until Analysis. ^{1}H-NMR, FTIR and iodine value were used in the analysis. The products were used as starting materials for the copolymers.

Percentage Oil yield determination
The oil yield was determined from the relationship.

$$\text{Percentage oil yield} = A\text{-}B \times \frac{100}{W}$$

Where:
A = weight of flask + oil
B = weight of flask only
W = weight of sample
Determination of Physiochemical parameters:
The iodine value, free fatty acid, saponification value and peroxide value were determined using standard techniques.
Iodine value measurement.
0.1g of the sample was weighed into 200ml flask. Solution is effected by adding 5ml of carbon tetrachloride, dried over calcium chloride, 10ml of the Wij's solution was added from a dry pipette, the flask is closed with a stopper and allowed to stand for few minutes. 5ml of 10% KI solution and 50 ml of water was added to the content. Titration was conducted with 0.1N sodium thiosulphate solution using 10 drops of 1% starch solution as indicator. A blank test, omitting the sample was simultaneously performed. Similar test was carried out for the PCPB. The iodine value was calculated using the formula:

$$\text{Iodine value} = \frac{(x\text{-}y) \times 1.269}{w}$$

where x = ml of thiosulphate solution required by the blank, y = ml of thiosulphate solution required in the test. w = weight of sample. The factor 1.269 is for an accurate 0.1N solution of sodium thiosulphate (AOAC, 1984).
Saponification value measurement
The saponification value was determined by taking 1.0 g of the oil sample in a conical flask to which was added 15 mL 1 N KOH and 10 mL of distilled water and heated under a reserved condenser for 40 min to ensure that the sample was fully dissolved. After this sample was cooled, phenolphthalein was added and titrated with 0.5 M of HCl until a pink endpoint was reached. A blank was determined with the same time conditions (Zahir et al., 2014).
Peroxide value measurement
1.0g of oil sample was dissolved in acetic acid then chloroform and saturated KI mixture were added. The iodine liberated from KI by the oxidative action of peroxides present in the oil was determined by titration with standard sodium thiosulphate using starch solution as the indicator. Titration was also performed for blanks (AOAC, 1984, Zahir et al., 2014).

$$PV\ (meq/kg\ oil) = (S\text{-}B) \times W \times N.$$

Where B is the volume of sodium thiosulphate used for blank, W is the weight of sample, S is the volume of sodium thiosulphate consumed by the sample oil and N is the normality of standard sodium thiosulphate.
Free fatty acids determination
The acid value was determined using the method described by Ronald (1991). Equal volumes of diethyl ether and ethanol were mixed together and 1ml of 1% phenolphthalein indicator solution was added and then neutralized with 0.1M potassium hydroxide solution. The oil was dissolved in the neutralized solvent mixture and titrated with 0.1M potassium hydroxide solution with constant shaking until a pink colour which persists for 15seconds is obtained.

$$\text{Acid value} = \frac{\text{Titre value (ml)} \times 5.61}{\text{Weight of sample used (g)}}$$

Preparation of copolymers from phenolated vegetable oils.
Homopolymerization of acrylamide and acrylonitrile.
Preparation of polyacrylamide(PAA)
1.5 litres of 30% wt./vol. acrylamide in water was transferred into a three necked batch reactor, 30ml of 0.05M $NaNO_3$ solution was added. The mixture was thoroughly stirred for few minutes under nitrogen gas. Fe^{2+}-H_2O_2 (Fenton's reagent) was added as initiator and this was stirred for 5 minutes. Nitrogen gas was bubbled through for sometimes. The reaction continued for the next four hours. After the desired reaction time, the reaction was terminated by adding 0.2 g hydroquinone powder and the contents were stirred for another some minutes before being stopped. The homopolymer was cleaned with ethanol to remove unreacted acrylamide, remnants of $NaNO_3$ solution and the catalyst. The product was allowed to dry for half a day over sodium sulphate to ensure the total

removal of the moisture content. It was kept in a cool dry place until the period of further application and analysis. The product was analysed with FTIR and ^{1}H-NMR.

Homopolymerization of acrylonitrile

100g of acrylonitrile was added to 200mL of distilled water in a 3-necked batch reactor equipped with a mechanical stirrer and gas inlet. Then 1.5g of Fenton's reagent (H_2O_2-Fe^{2+}) was added to the acrylonitrile solution. The mixture reacted at 90^0C for 3 h. Then, the precipitates were collected by filtration, washed with acetone, and dried under vacuum at room temperature, yielding Polyacrylacrylonitrile.

Copolymerization reactions.

The copolymerization reaction of PCPB with polyacrylamide and Polyacrylonitrile was performed using the same method in a 1 L isothermal three-necked batch reactor, equipped with an overhead stirrer and a temperature regulator to allow the control of the reaction temperature. The catalysts employed are Fenton's reagents (Hydrogen peroxide + Ferric ammonium sulphate in 1:1). The copolymerization reactions were carried out using a hybrid of the methods described by Witono in 2012 and Nur Azmyra et al., 2014.

PCPB was loaded into the reactor and mixed with a known volume of distilled water. The mixture was thoroughly stirred for some minutes under nitrogen gas environment. This was followed by the addition of predetermined amount of homopolymerized polyacrylamide to give specific ratios. The mixture was stirred for 5 minutes and was heated under nitrogen gas atmosphere at 70^0C for 25 minutes. The temperature was reduced to 60^0C for the first two and increase to 80^0C for the last 4. Each of the reaction continued for 5 or 6 hours. The reaction was ceased by adding 2 ml of 0.1 M hydroquinone and the contents were stirred for another 10 minutes before opening the reactor to collect the samples. The copolymerized phenol and vegetable oils and the various homopolymers were separated from the unreacted homopolymer by washing a representative sample of 30 g from the reaction contents with 40ml of acetone for several times until homopolymer could not be detected in the supernatant. The product obtained was dried and then transferred into separate labelled containers for analysis and applications.

Analytical techniques

The oil, PCPB and the synthesized copolymer precursors were analysed using a ^{1}H-NMR techniques. The NMR analysis were carried out using Agilent - 400 MHz, temperature of 31^0C and $CDCl_3$ as solvent, FTIR was used to monitor the change in functional groups. This was done by using Perkin Elmer FTIR system spectrum BX. Viscometry was used to monitor the change in molecular weights. Details of results are in the next chapter.

Results and Discussion

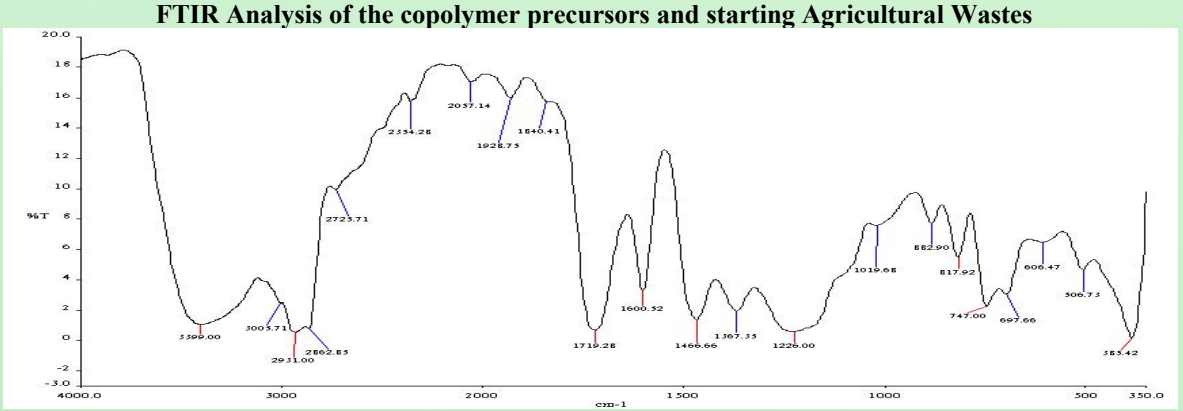
Table 1: Physicochemical analysis of oil

Samples	Oil yield (%)	Iodine value of oils (gI_2/100g)	Iodine value of PCPB(gI_2/100g)	Peroxide value (meq/kg)	Saponification value (mgKOH/g)	Free fatty acids (%)
Carica papaya oil	32.22	99.55±0.38	61.98±0.06	10.56±0.51	186.39±0.42	7.56±0.07

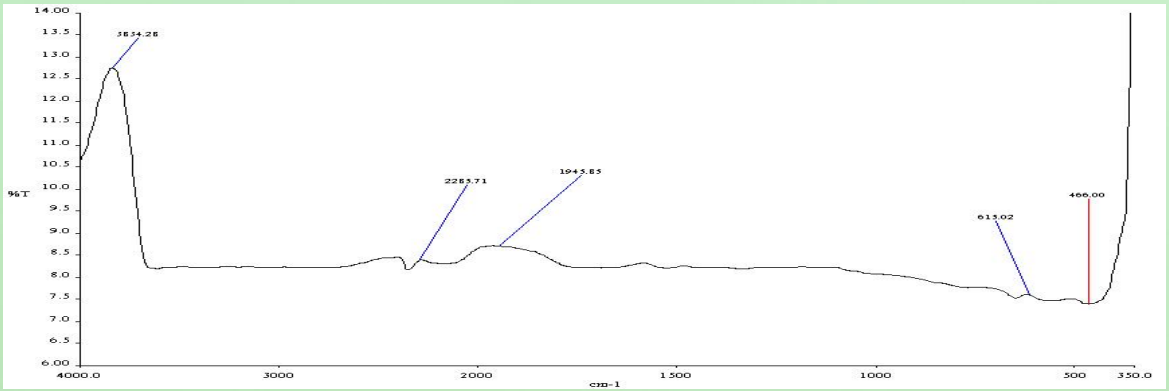
Mean value ±standard deviation (n=3).

The oil yield for this sample is 32.22%. This suggests that the oil quantity is of commercial viability for the production of oleo chemicals. It is also in the range of values reported for most oil employed for polymerization processes such as Neem seed oil, soya bean oil, rape seed oil and lots more. The oil showed an iodine value of 99.55±0.38(gI_2/100g) to suggest it's a semi drying oil. This feature shows that the oil is rich in unsaturation. Literature works on the oil confirmed it to be rich in oleic acid. This level of unsaturation suggests that the oil has potential features of been deployed into chain growth polymerization techniques, be it cationic, anionic or free radical. The PCPB showed a lesser iodine value(Table 1) to suggest that grafting of phenol to the oil(triglyceride) backbone occurred at the vinyl groups present in the oil moiety. This led to a reduction in the number of vinyl groups within the *Carica papaya* oil sample (Oladiji et al., 2010). Peroxide value is an indicator of oil's rancidity. Values lower than 10 ml/kg does not show rancidity but values around 30 to 40 ml/kg suggest that the oil may be rancid. PCPB showed a value of 10.56±0.51 meq/kg to suggest that it is extremely low in rancidity or less oxidized. A non-rancid oil gives information about its stability, the high stability of this seed oil shows that it has the potential to be modified into suitable product(s) of interest. Saponification value of the oil (Table 1) is the range coated in literatures for seed oil. The saponification value of the oil suggests that oil is rich in unsaturated fatty acids. This also complement the iodine value result and affirm the suitability of the oil for chain growth polymerization processes. The free fatty acid gives information about oil quality, a low value of free fatty acid suggests better oil and complement the peroxide value result for the sample. The oil's free fatty 7.56±0.07% to show that its of good quality and stability. The physicochemical analysis outcome suggests that the seed oil sample which is an Agricultural wastes has viable features that can convert it to useful starting material in the chemical industries. This will inevitably create a market for this agricultural waste and similar others with minimal impairment to the environment.

FTIR Analysis of the copolymer precursors and starting Agricultural Wastes

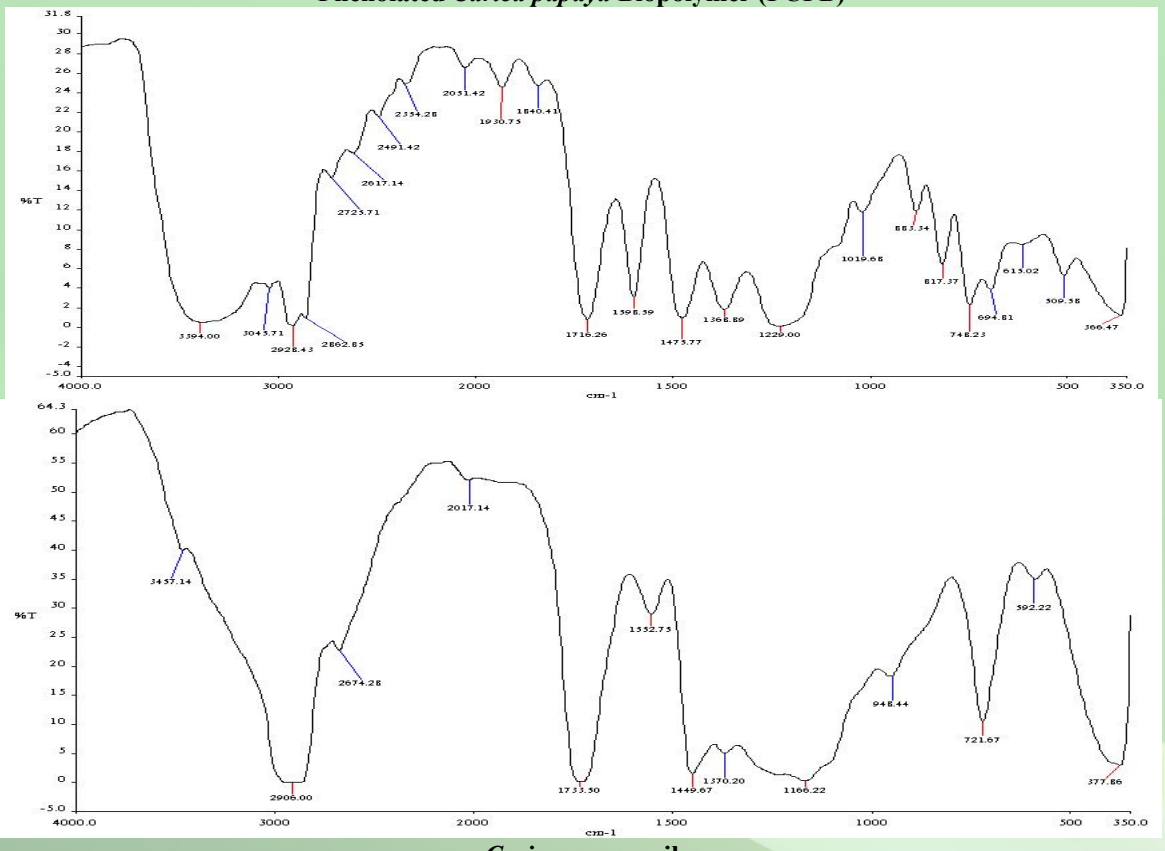


PCPB-PAA



Polyacrylamide (PAA)

Phenolated *Carica papaya* Biopolymer (PCPB)



***Carica papaya* oil**

Figure 1: **FTIR spectra of the copolymer precursors and starting Agricultural Wastes**

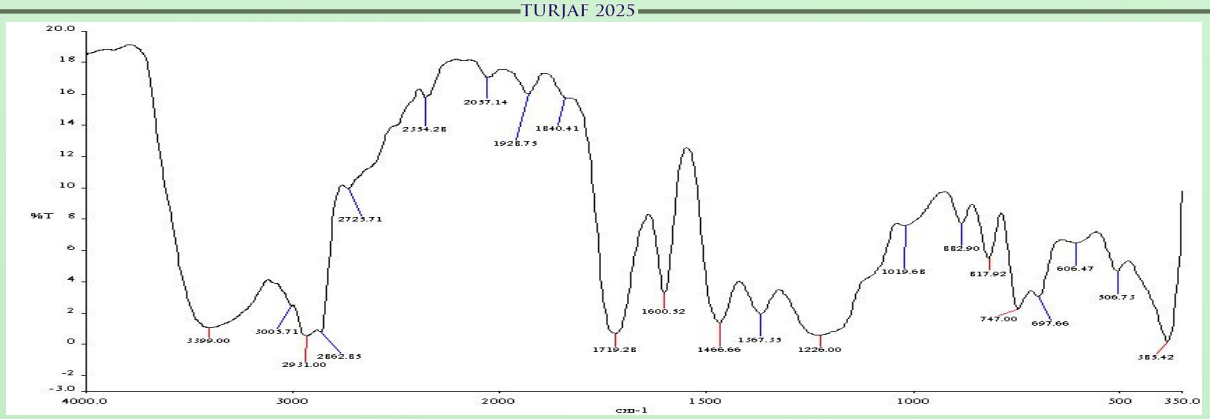
The spectrum of *carica papaya* oil (Figure 1) showed a carbonyl group of an ester at 1733.50 cm^{-1}, C-O band at 1166.22 cm^{-1} and a C-H band at 2906.00 cm^{-1}. This bands confirmed this oil to be a fatty esters. This establishes the literature reports that triglycerides are majorly esters. The peaks at 1449.67 cm^{-1}, 948.44 cm^{-1} and 721.62 cm^{-1} confirm C-C stress and C-H bend of aromatics and vinyl groups in the triglyceride moiety. This shows that the crude sample contain some phenolic. The peak at 1552.75 cm^{-1} serves as evidence that the oil is rich in substituted alkene. This complements the result of the physiochemical parameters for the sample. This peak affirms that the oil can undergo addition polymerisation processes. The presence of ester and vinyl functional groups in this agricultural waste carica papaya seed oil show that it can be a viable feedstock in producing useful industrial chemicals precursors (Takahashi et al., 2008). The carbonyl group in the fatty ester is an evidence that the products from this feedstock will be biodegradable and photodegradable.

Polymerising phenol and the *Carica papaya* oil produced Phenol *Carica papaya* biopolymer (PCPB). The spectrum is presented in Figure 1. Strong C=O stretch of ester was found at 1716.26cm^{-1}, C-O stretch was confirmed at 1229.00cm^{-1} and 1019.68cm-1. These peaks confirmed the existence of the triglyceride in the new material. This shows that grafting did not occur at the ester/triglyceride group since there is no hydrolysis. C-C stretch band of aromatics was confirmed at 1475.77cm^{-1} and C=C. Stretching vibrations of arene occurred at 1552.75cm^{-1} to show that the new material contains phenolic. The starting material also show the presence of phenolics but the number of C-H bending vibration in PCPB outweighs those in the oil to confirm grafting (Figure 1). The oil shows two C-H bending vibrations at 948.44cm^{-1} and 721.62cm^{-1} while the PCPB showed 4 distinct C-H bending vibrations of aromatic at 883.34cm^{-1}, 817.37cm^{-1}, 748.23cm^{-1} and 694.81cm^{-1} to affirm the grafting process. O-H stretch of phenolic was similarly affirmed at 3394.00cm^{-1}. The grafted oil showed additional reactive groups through the phenolic/arene on its backbone and hence may be deployed as biodegradable alternatives alkenes in the production of materials such as bio-plastics, bio-polyvinyl chlorides and other bio-polymeric materials.

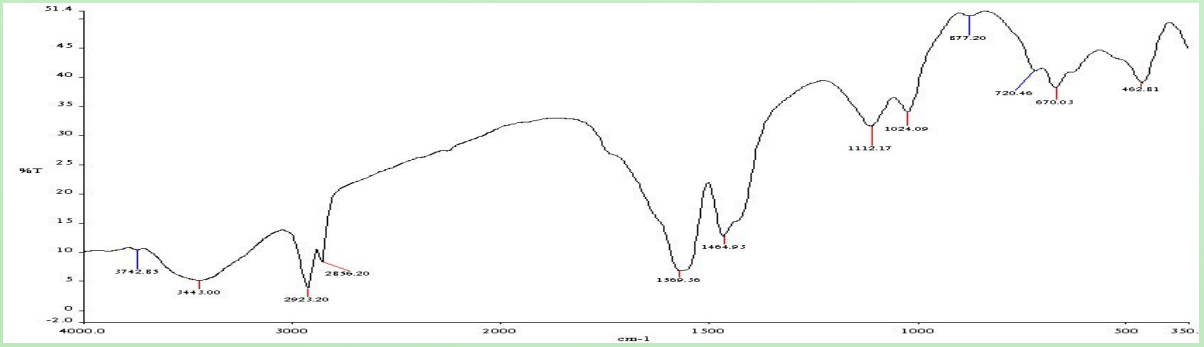
In this research, it was deployed to the production of copolymer by grafting PAA unto its backbone. The spectrum of the polyacrylamide that was synthesized showed C=O vibrational stretch at 1680.00cm^{-1}. C-N stretch band peak occurred at 2285.71cm^{-1}. C-H bend of alkenes was found around 615.02cm^{-1} to show that the PAA homopolymer is unsaturated. PCPB-PAA is the grafted copolymer material from the agricultural waste. The spectrum showed the presence of C=O stretch of esters at 1711.21cm^{-1} , C-O stretch occurred at 1025.38cm^{-1} and C-H stretch appearing as a doublet occurred at 2927.57cm^{-1} and 2862.85cm^{-1} . These peaks similarly establishes that the ester and triglyceride moiety is still present in the new copolymer material. The spectrum also showed invaluable bands at 2354.28cm-1 and 3472.24cm-1 to suggest that C-N stretch and N-H stretch are present in the new material. These bands are commonly found in amides and are absent in the starting material. They are evidences that the polyacrylamide was grafted to the PCPB backbone. The bands occurring at 1600.46cm-1, 1465.18cm-1 are due to C=C stretch of aromatics and C-C stretch of aromatics. They confirm that the phenolic group is still present in the new copolymer. C-H bend of aromatics were also found within the finger print region at 948.44cm^{-1}, 885.75cm^{-1}, 819.30cm^{-1} and 697.36cm^{-1} to affirm this observation. The multiple reactive groups in the copolymer makes it a good starting precursor for various industrial chemical synthesis. This material can therefore be a substitute to styrene, propene, but-1, 3 diene and lots more in industrial processes as a precursor (Srikanth et al., 2022). Exploring the *Carica papaya* oil also yielded another copolymer with the IR details presented in Figure 2.

The *carica papaya* and phenol *carica papaya* biopolymer (PCPB) have been earlier discussed in Figure 1. Polyacrylonitrile was employed as the second grafting parameter to the PCPB. The spectrum is presented in Figure 2. The spectrum confirms PAN bands at 1569.36cm^{-1} and 1464.93cm^{-1} stretching vibration. This occurred due to high crosslinking and ladder-like structure within the PAN homopolymer moiety. Methylene group vibration occurred at 2923.20cm^{-1} and 2856.20cm^{-1}. They are attributed to the loss of hydrogen atoms as part of the hydrogenation process. Copolymerizing the PCPB and PAN produces PCPB-PAA. The spectrum is presented in Figure 2. The spectrum showed similar features as found in the triglyceride with C=O stretch occurring at 1719.28cm^{-1} and C-O band vibration found at 1226.00cm^{-1} and 1019.68cm^{-1}. C=C stretch of alkenes/arene occurred at 1600.52cm^{-1} to affirm unsaturation within the newly synthesized PCPB-PAA material. It shows that the grafting process occurred within the vinyl moiety. The C=C bending vibrations were found at 882.92cm^{-1}, 817.92cm^{-1}, 747.00cm^{-1}, 697.66cm^{-1}, 606.47cm^{-1} and 506.73cm^{-1} as additional factors suggesting the vinyl and aromatic groups in the new copolymer. The evidence of the cross-linked polyacrylonitrile in the new material was found at 1466.66cm^{-1} and 1387.35cm^{-1} . This affirm that the Polyacrylonitrile was grafted to the PCPB backbone. ^{1}H-NMR was further used to confirm this.

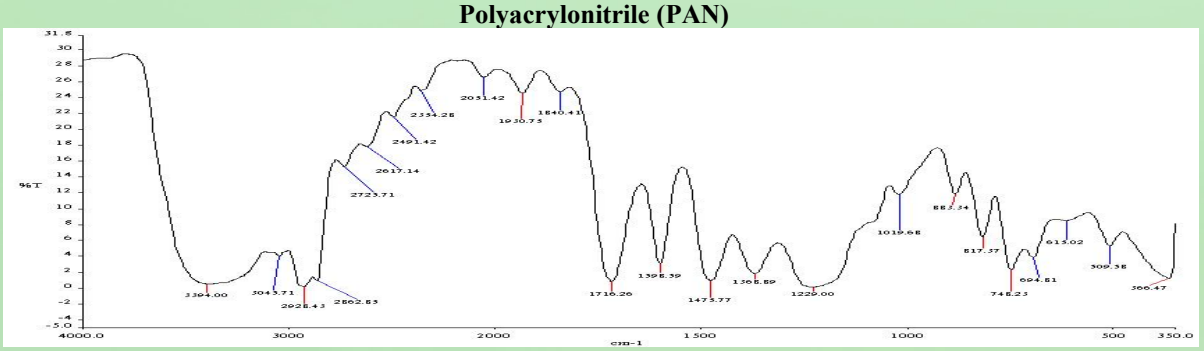
Figure 3 shows the various chemical environments in the carica papaya oil and the industrial precursors from it. The spectrum of carica papaya oil showed five different chemical environments ^{1}H NMR (400 *Carica Papaya* oil (MHz, $cdcl_3$) δ 5.47 (s, 0H), 2.44 (s, 1H), 2.14 (s, 1H), 1.41 (s, 7H), 1.01 (s, 1H). The peak at δ 5.47ppm is for vinyl protons within the oil sample. It is similarly confirmed by the FTIR result for the sample. Substituted carbonyl peaks were found at δ 2.44ppm and δ 2.14ppm as evidences for ester functional group within the oil moiety. Substituted saturated protons common to triglycerides occurred at δ1.41ppm and δ 1.01ppm as singlet. The presence of vinyl protons in the oil affirm its ability to undergo addition polymerization.



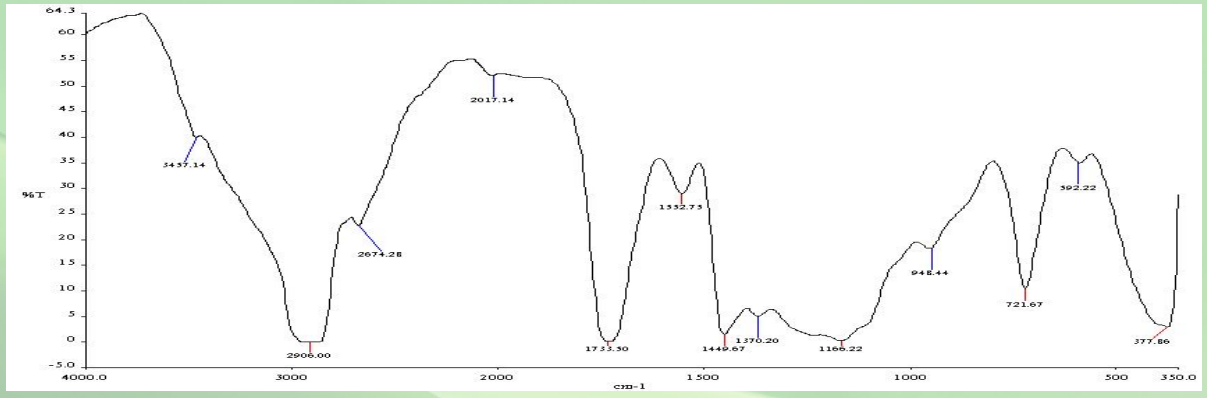
PCPB-PAN



Polyacrylonitrile (PAN)



PCPB



***Carica papaya* waste seed oil**

[1]H NMR spectra of *Carica Papaya* oil and some possible precursors



Figure 3: [1]H NMR spectra of *Carica papaya* oil and some possible precursors

Copolymerizing phenol and the carica papaya oil produced the PCPB. The spectrum is also presented in Figure 3. It shows that the new chemical environments different from those in the oil has been introduced which resulted from the introduction of the phenolic group to the oil's backbone. The chemical environments from the spectrum are highlighted as [1]H NMR of Phenol *Carica Papaya* Biopolymer (PCPB) (400 MHz, cdcl$_3$) δ 8.11 (s, 2H), 7.80 (s, 1H), 7.72 (s, 1H), 6.23 (s, 0H), 3.20 (s, 1H), 2.89 (s, 1H), 2.49 (s, 1H), 2.15 (s, 7H). The peaks at δ, 8.11ppm, δ, 7.80ppm, δ, 7.72ppm and are evidences of substituted protons in the new material. These peaks were absent in the CPO. They therefore affirm that the grafting process occurred. This result was confirmed by the FTIR details for the sample. δ,6.23ppm is also an evidence that the new product is still unsaturated. The higher downfield absorption confirms the effect of the phenolic group on the unsaturated component of the oil. Integrating Polyacrylamide to the PCPB backbone produces PCPB-PAA. The spectrum also is presented in Figure 3 and labelled. It shows several distinct chemical environments form the starting materials. [1]H NMR PCPB-PAA (400 MHz, cdcl$_3$) δ 7.18 (s, 1H), 6.86 (s, 3H), 5.52 (s, 1H), 5.36 (s, 1H), 4.15 (s, 1H), 2.36 (s, 2H), 2.28 (s, 1H), 2.02 (s, 2H), 1.94 (s, 1H), 1.27 (s, 23H), 0.89 (s, 2H), 0.82 (s, 1H). Peaks at δ 7.18ppm, δ 5.52ppm and δ , 5.36ppm

occurred due to the formation of substituted amide and occur as singlet in the spectrum. Peak at δ, 6.86ppm are evidences of highly substituted phenolic group in the new polymeric material. It affirms the presence of PCPB in the new material. The peak at δ, 4.15ppm is an evidence of phenolic protons. It further confirms the grafting process. Carbonyl peaks showing the presence of the ester and triglyceride group moiety in the new polymeric material were affirmed with peaks at δ2.36ppm, δ 2.28ppm and δ2.02ppm. Substituted allylic protons occurred at δ , 1.94ppm. They serve as new reactive centre in the new material. Several authors have confirmed that allylic centres are reactive points in vinyl compounds. Substituted saturated protons were found at δ, 1.27ppm. The large values of the singlet emanates from the hydrogenation occurring at vinyl groups and aromatic groups during the cationic polymerization processes. Other saturated protons in the spectrum are δ, 0.82ppm and δ,0.89ppm. They are further evidences for the further hydrogenation processes. Another copolymer from the PCPB was termed PCPB-PAN. It was formed by copolymerizing with PCPB and Polyacrylonitrile (PAN). The spectrum is also presented in Figure 3. The various chemical environments from the spectrum is ^{1}H NMR for PCPB-PAN (400 MHz, cdcl$_3$) δ 4.89 (q, J = 8.8 Hz, 1H), 1.94 – 1.81 (m, 3H), 1.54 (q, J = 6.5 Hz, 1H), 1.19 (s, 6H), 1.15 (q, J = 7.4 Hz, 1H), 0.96 (s, 2H), 0.90 – 0.83 (m, 4H), 0.86 – 0.76 (m, 6H), 0.41 (t, J = 6.6 Hz, 1H).

The peak at δ 4.89ppm is an evidence for the nitrile formation in the new copolymer. There are no aromatic protons in the spectrum to suggest that the phenolic group in the starting material and vinyl moiety1256that reacted with the polyacrylonitrile have been hydrogenated during the free radical reaction process. This may have resulted from the ability of the Fenton's reagent (catalyst) deployed in the reaction to form categories of intermediates and resonances which had initialized series of reaction while the polymerization was been carried out and had led to the final product observed. Peaks at δ 1.94 – 1.81 (m, 3H) range confirm allylic protons in the new material. The high level of saturation occurring at δ ppm 1.19ppm, δ1.15ppm, 0.96ppm, δ 0.90 – 0.83ppm (m, 4H), δ ,0.86 – 0.76 (m, 6H), 0.41 (t, J = 6.6 Hz, 1H) affirm that phenolic group and vinyl group had been heavily hydrogenated. The result from copolymerizing PAN and PCPB differ greatly from that observed in PAA and PCPB. The drastic observations may have resulted from the triple bonds associated with nitriles and its ease of hydrolysis with acids. The two copolymers spectra analysis affirm that polymerizing carica papaya can be depended upon in producing useful industrial precursors. The new materials shows promising functional groups like amide, arenes, vinyl groups, nitrile, esters and alcohols that can be exploited as precursors for petrochemical companies in polymer production, oil and gas industries in producing oil field chemicals (Falah et al., 2020). The viability of these precursors is in the renewability and availability. They can therefore become long term alternative to fossil fuel in keeping the chemical industries on track with minimal environmental and ecological derails.

Mean molecular weight determination

Table 2:Viscometry analysis results of synthesised Carica papaya oil biomaterials

Biomaterial	Mean Molecular weights (g/mol.)	Copolymers	Average Molecular weights(g/mol.)
PCPB	7.482 x10^{9}	PCPB-PAA	1.062 x 10^{12}
		PCPB-PAN	1.558 x 10^{12}

Keys:
Phenol *Carica papaya* biopolymer (PCPB)
Phenol *Carica papaya* biopolymer-polyacrylamide (PCPB-PAA)
Phenol *Carica papaya* biopolymer-polyacrylonitrile (PCPP-PAN),

The above molecular wrights were determined from Mark-Hauwink Sakurada techniques through the calculations of the flow rates and various viscosities like specific viscosities, intrinsic viscosities', reduced viscosity and inherent viscosity. The results of the viscometry technique are in tandem with the FTIR and ^{1}H-NMR for all the biomaterials considered. The mean molecular weight of the copolymers are greater than the starting PCPB to show that the grafting between PCPB and PAA occurred (Table 2). This was confirmed for the PCPB-PAN. The results affirmed that through various polymerization techniques, seed oils which are agricultural wastes can be used to generate using materials similar to those from petroleum industries and as alternative biodegradable feedstock source. The results showed that there is no part of the Agricultural material that is a waste. The copolymers and phenolated material from the seed oil have the potential to become viable industrial precursors through the right unit operations and unit processes.

Conclusion

The feasibility of producing industrial precursors from seed oils was examined using carica papaya seed as sampled study. The first phase of the research after sample collection and preparation was to extract oil from the carica papaya seeds. The next phase was the determination of the physicochemical properties of the oil extracted oil. The oil contains high iodine value to make it semi drying oil. Saponification value was similarly high and in the expected trend. Free fatty acid value of the oil is in the standard range to affirm no rancidity or oxidation. The third phase was to polymerized the oil with phenol to yield the phenolated intermediate which was identified as

Phenolated *Carica papaya* biopolymer(PCPB. Homopolymers of acrylamide and acrylonitrile were prepared and characterized using FTIR.

The PCPB and polyacrylamide were copolymerized using free radical polymerization method to obtain the corresponding copolymer termed PCPB-PAA. Similarly PCPB and the synthesized PAN were copolymerized to yield the copolymer termed PCPB-PAN. They were all characterized using FTIR to determine the functional groups. ^{1}H-NMR was used to determine the various chemical environments. Viscometry technique was used to measure the flow rates while Mark-Hauwink Sakurada relation was used to estimate the average molecular weights. The new copolymers showed characteristics features of ester, amide, nitrile, alcohols, arenes and vinyl to establish that they possess enough active sites that can make them viable industrial precursors and compete favourably with their counterparts form finite sources like crude oil, coal and shale oil. This research therefore creates environmentally friendly ways of converting agricultural wastes into useful starting materials for the chemical industries. This will increase the economic value of these wastes and ensures that they have improved value chain to the farmers, regions and countries where they are found in large amount such as Nigeria. They will therefore improve the nation's GDP. They are also environmentally friend and photodegradable. Hence they will contribute in mitigating the unpleasant effects of green house gases. This serves as a major route to the sustainability of the green chemistry policies and sustainable development goals (SDGs).

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Authors' individual contribution:

Dr. Olakunle Alex Akinsanoye was involved in the experimental design, carrying out the experiment, analysis of results, financing and manuscript design.

Professor Olugbenga A. Falode was involved in the composition, result analysis, financing and proof reading of the manuscript.

Professor Mopelola Abeke Omotoso was involved in the conception of the work, financing and guide throughout the research.

Conflict of interests: The authors declare no known financial or personal conflict of interests that influence the work reported in this manuscript.

Data and Code available: Not Applicable

Supplementary information: The flow sheet and viscosity calculations are presented as supplementary information.

Ethical Approval: Not Applicable in this research.

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Supplementary information for viscometry analysis

Flow rate, concentration and calculated viscosities for PCPB

Flow rates (s)	Concentrations (g/ml).	Relative Viscosity (t/t_0)	Specific viscosity (η_r -1)	Reduced viscosity (η_{sp}/C)	Inherent viscosity $In\eta_r/C$
46.0±0.14	-	-	-	-	-
93.4±0.11	4.44 x10^{-4}	2.03	1.03	2319.82	1609.17
146.3±0.13	8.88 x 10^{-4}	3.18	2.18	2454.95	1302.79
200.0±0.00	13.3 x 10^{-4}	4.35	3.35	2518.80	1105.40
261.0±0.14	17.8 x 10^{-4}	5.67	4.67	2623.60	974 .83
314.6±0.14	22.2 x 10^{-4}	6.84	5.84	2630.63	866.12

Table 2. Flow rate, concentration and calculated viscosities for(PCPB-co- PAA)

Flow rates (s)	Concentrations (g/ml)	Relative Viscosity (t/t_0)	Specific viscosity (η_r -1)	Reduced viscosity (η_{sp}/C)	Inherent viscosity $In\eta_r/C$
57.0±0.41	-	-	-	-	-
123.0±0.41	4.44 x10^{-4}	2.16	1.16	2612.62	1734.45
214.0±1.55	8.88x 10^{-4}	3.75	2.75	3094.84	1488.46
293.0±0.07	13.3x 10^{-4}	5.14	4.14	3112.78	1230.87
345.0±0.07	17.8 x 10^{-4}	7.10	6.10	3426.97	1101.18

ble 3. Flow rate, concentration and calculated viscosities for (PCPP-co-PAN)

Flow rates (s)	Concentrations (g/ml)	Relative Viscosity (t/t_0)	Specific viscosity (η_r -1)	Reduced viscosity (η_{sp}/C)	Inherent viscosity $In\eta_r/C$
21.0±0.02	-	-	-	-	-
35.1±2.16	2.50 x10^{-4}	1.67	0.67	2680.00	2051.29
49.6±1.55	5.00 x 10^{-4}	2.63	1.36	2720.00	1717.30
65.0±1.55	7.50 x 10^{-4}	3.10	2.10	2800.00	1508.54
82.3±1.55	1.00 x 10^{-4}	3.92	2.92	2920.00	1366.09

ID: 692

Investigation of Factors Influencing Solubility of Whey Protein Hydrolysate-Skim Milk Powder Mixtures

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Abstract

Whey protein hydrolysate (WPH) and skim milk powder (SMP) offer nutritional and functional properties of milk proteins. Physicochemical changes during rehydration alter solubility, which is an important techno-functional property of milk powders that may limit their regular usage in food products such as ready-to-drink beverages. This study explored how mixing WPH with SMP and chelating salt affects its solubility in a protein mix. SMP34 and WPH80 were mixed in various ratios, with trisodium citrate added at concentrations from 0 to 2.5% and rehydrated in ultrapure water. The effects of SMP and trisodium citrate on the solubility of WPH, particle size distribution, zeta potential, buffering capacity, pH and colour were investigated. The resulting data were analyzed using Minitab version 14. At 10% and 20% SMP-WPH total solids content (w/v) blend, solubility increased significantly ($P< 0.05$) from 68.9 to 63.5%. There was no significant ($P>0.05$) effect observed on zeta potential with increasing trisodium citrate concentration in the mixtures. However, the protein mixtures demonstrated colloidal stability. The study demonstrated an increase in the solubility of milk protein powder blends with the addition of trisodium citrate, potentially increasing the value of dairy ingredients and their application in new categories of ready-to-drink protein beverages.

ID: 694

Assessing The Physicochemical Composition And Wide Diversity Of Pollen In Honey Samples Procured From Some Markets In Umudim Local Government Area Of Anambra State

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Abstract

A range of honey varieties can be found in Nigerian markets. In the present study, a comprehensive analysis of four honey samples collected from various locations (Eke Osu, Afor Eziama, Eke Amichi and Nkwo-Igbo) in Umudim Local Government Area of Anambra State was carried out with the aim of evaluating the wide diversity of pollen and physicochemical composition of the honey samples using standard methods. A total of forty six (46) distinct pollen types in 22 plant families were recorded. Inclusively, the varying percentage counts of the entire samples were: 650 (22.26%) in Eke osu, 825 (28.25%) in Afor Eziama, 755 (25.86%) in Eke Amichi and 690 (23.63%) in Nkwo Igbo. The frequency class highlighted the presence of pollen types such as *Allophylus africanus*, *Lannea acida*, *Piliostigma* sp. and *Elaeis guinensis*, which were classified as secondary types. The results of the physicochemical composition showed that the samples had pH values ranging from 4.00 - 5.00, moisture (7.60% - 8.21%), ash (0.09% - 1.20%), protein (1.36% - 1.98%), fat (1.05% - 1.43%), polyphenol (60.73% - 84.48%); free acidity (46.00 - 59.00 meq kg-1) and HMF (46.60 – 54.40 mg/kg). Sugar composition analysis showed that the recorded values of fructose and glucose were: Eke osu (57.00±1.73 Mg/100g), Afor Eziama (50.00±0.58 Mg/100g), Eke Amichi (49.00±0.11 Mg/100g) and Nkwo Igbo (53.00±0.33 Mg/100g) for fructose; Eke Osu (43.00±1.15 Mg/100g), Afor Eziama (44.00±0.58 Mg/100g), Eke Amichi (39.00±0.81 Mg/100g) and Nkwo Igbo (49.00±0.42 Mg/100g) for glucose. Higher values were recorded for sucrose. The results demonstrated that most of the parameters aligned with recommended standard of quality honey. Hence, they are good for human consumption.

Key words: *honey samples, physicochemical composition, pollen types, markets, frequency class*

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ID: 695

Morphological Characteristics of Apple Genotypes in Mudurnu (Bolu)

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Abstract

This research was carried out in the Mudurnu district of Bolu province to determine the morphological and chemical properties of 17 apple genotypes. Fruit and seed properties and soluble solids content, pH, titratable acidity, and fruit color (L*, a*, b*, chroma*, and hue°) were examined. Descriptive statistical analysis, principal component analysis, and hierarchical clustering analyses were used to determine the morphological and chemical properties of the genotypes. Fruit weights were determined as 29.06-126.30 g, fruit width as 30.55-74.00 mm, fruit flesh firmness as 2.40-7.00 kg/cm^2, soluble solids content as 12.00-18.21%, and pH as 2.93-5.30 in the examined genotypes. It was determined that G3 and G13 genotypes differed from the other genotypes regarding the examined properties. The genetic diversity identified in this study provides a valuable foundation for breeding programs aimed at developing new apple cultivars that are adapted to regional conditions and meet market demands. Particularly, the distinct genotypes such as G3 and G13 are significant due to their potential use as parents in future selection studies or hybridization programs.

Key Words: *Apple, Genotypes, Selection, PCA, Pomological characteristics*

Introduction

Anatolia, thanks to the ecological opportunities offered by various climate zones and soil structures, allows the growth of many fruit species. Among these fruit species, the apple belongs to the *Malus* genus of the *Rosales* order, *Rosaceae* family, and *Pomoideae* subfamily (Kaşka, 1977). Its origin is the South Caucasus region, including Anatolia (Özbek, 1978). Apple, open to foreign pollination, produces many genotypes with the germination of heterozygous seeds. Today, many local and cultural apple varieties have emerged with selection studies conducted with genotypes (Karadeniz et al., 2013). There are 6,500 local apple varieties worldwide, and approximately 500 in Türkiye, suitable for different ecologies (Özmen and Çekiç, 2021).

The emergence of superior genotypes through targeted selection with selection breeding is an important step. Genotypes grown from natural seeds are valuable sources for increasing the quantity and quality of essential traits such as adaptation to ecological conditions, fruit characteristics, resistance to abiotic and biotic stresses, and nutritional quality due to environmental factors. The emergence of genotypes showing these superior traits is possible with selection breeding studies. Many researchers have used morphological and biochemical markers to reveal genetic diversity (Kaya and Balta, 2009; Bostan and Yılmaz, 2015; Vurgun and Aslantaş, 2016; Kara, 2022; Dumanoglu et al., 2018; Korkmaz and Okatan, 2021; Alan et. al., 2024), molecular (Vurgun, 2012; Güneş, 2017; Daler et al., 2017; Doğru Çokran et al., 2019; Koçyiğit, 2022; Bakır et al., 2022). Although these parameters are affected by genetic structure and environmental conditions, they provide valuable information about the differences and similarities between genotypes (Ebrahimi and Alipour, 2020). It is essential to maintain apple genetic diversity. The basic step in variety development and improvement is to collect and evaluate local germplasm. Multivariate analysis effectively interprets the relationships between genotypes for germplasm characterization (Al-Halabi, Muzher, 2015). This research aimed to determine the fruit traits of apple genotypes in Mudurnu/Bolu province and to reveal their diversity using multivariate analysis methods.

Material and Methods

This research was conducted on 17 apple genotypes grown from seeds found in nature in the Mudurnu district of Bolu province, where no cultural practices were applied. Ten fruit samples were selected to represent each genotype for evaluation. Fruit weight (g) and seed weight (g) were measured with a precision scale, and fruit length (mm), fruit width (mm), seed width (mm), and seed length (mm) were measured with a digital scale. Seed number was obtained by counting the seeds in the carpel of each genotype. Fruit flesh firmness (kg/cm^2) was determined with a hand penetrometer. Soluble solids content (SSC) (%) were determined with a hand refractometer. pH was determined using a pH meter and the titratable acidity (TA) titration method as a percentage. Fruit taste was determined by five panelists giving a score between 1-5. Fruit color (L*, a*, b*, Chroma*, and Hue°) was determined with a colorimeter.

Statistical Analysis

Descriptive statistical analysis was performed for fruit traits of genotypes. Principal Component Analysis (PCA) and Hierarchical Cluster Analysis were conducted to determine the relationships between the examined fruit traits and genotypes. JMP software was used in statistical analyses.

Results and Discussion

Descriptive statistical data of the characteristics examined in apple genotypes are given in Table 1. The analyzed genotypes showed wide variation. The coefficients of variation of the traits studied in genotypes varied between 8.92% (Seed length) and 69.68% (TA). It was determined that fruit and seed weight, seed number, TA, a*, b*, and Hue^o values had high variation (% CV ≥ 35.00). This variability shows that some traits showed more variance than others. A high CV value can clearly distinguish the genotypes regarding these traits and indicate diversity and variability. It was determined that a lower % CV ≤35.00) was found in other pomological characteristics examined. This situation shows that apple genotypes are more consistent regarding these traits.

Fruit weight ranged between 29.06 and 126.30 g, and the coefficient of variation was 36.78% (Table 1). Fruit weight was determined as 26.59-273.75 g by Özmen and Çekiç, (2021), 65.40-205.30 g, Balta et al. (2015), 71.41-245.99 g, Kırkaya et al. (2014) 76.24-247.23g, Uzun et al. (2016) 75.52-191.95 g, Macit and Aydın (2021) 59.3-220.8 g, Özrenk et al. (2011), 20.90-139.30 g, Macit et al. (2021) reported it as 27.56-269.32 g. In our research, fruit length and width varied between 32.38-60.35 mm and 30.55-74.00 mm, respectively. The coefficients of variation are 12.44% and 15.10%, respectively. Fruit length and width were reported as 53.17-81.77 mm and 62.97-91.87 mm by Yarılgaç et al. (2009), 50.3-73.06 mm and 51.65 mm - 75.34 mm by Çöçen et al. (2019), 50.96-78.95 mm and 61.01-95.59 mm by Karadeniz et al. (2013) reported it as 53.14-62.07 mm and 63.46-73.79 mm, Bostan and Acar (2009) as 43.85-74.61 mm and 53.40-86.60 mm, Kırkaya et al. (2014) as 69.03-89.03 mm and 60.96-73.98 mm, Uzun et al. (2016) as 46.81-65.57 mm and 60.61-78.60 mm, Macit and Aydın (2021) as 48.3-67.3 mm and 50.4-85.0 m, Özrenk et al. (2011) as 32.8-54.3 mm and 35.4-60.3 mm. Findings from other researchers show a wide range of these properties. These findings show similar results to previous studies, but some differences may be due to genotypic and ecological conditions, especially genetic structure. Indeed, fruits are characterized by different shapes and sizes. Still, each fruit originates from the development of a single growing meristematic point, and the final size depends on the number of cell divisions and cell expansion during the development of the ovary and fruit. Individual fruit shape and size are determined by the fruit's genetics, phytohormones, and environment (De Mori and Cipriani, 2023) and can vary significantly among different genetic materials (Kumar et al., 2012).

In the genotypes, SSC varied between 12-18.21%, pH between 2.93-5.30, and TA between 0.17-1.88%. TA gave the highest coefficient of variation among the examined traits, at 69.68% (Table 1). Similarly, other researchers reported the SSC, pH and TEA values as 9.2-19.7%, 4.0-5.2%, 0.21-1.40% (Özmen and Çekiç, 2021), 8.40-14.25%, 3.03-4.10, and 0.16-1.08% % (Karakaya et al., 2016), 10.62-13.85%, 3.60-4.82% and 0.699-0.929% (Yarılgaç et al., 2009), 10.07-14.10%, 2.20-3.65% and 0.66-1.12% (Çöçen et al., 2019), 9.40-13.60%, 2.83-4.11% and 0.22-2.01% (Balta et al., 2015). In addition, Osmanoğlu and Balta (2021) reported the SSC values as 9.00-15.00%, Şenyurt et al. (2015) as 11.50-15.25%, and TA as 0.20-1.24%. Findings give slightly higher results than the findings of other researchers. However, SSC is one of the essential quality criteria in fruits, and SSC increases as fruit maturity progresses and reaches the maximum level on the harvest date. It is essential to evaluate SSC and other parameters such as TA and fruit flesh firmness, especially in determining maturity (Yer and Erdoğan, 2022).

In the genotypes examined, seed weight was determined as 0.12-0.55 g, seed length as 6.07-9.38 mm, seed width as 2.71-5.41 mm, and seed number as 1-10 (Table 1). They reported seed weight, seed length, seed width and seed number as 0.20-0.55 g, 7.46-10.59 mm, 3.84-5.58 mm and 3.5-10 pieces (Yarılgaç et al., 2009), 0.02-0.08 g, 7.23-9.11 mm, 3.45-5.28 mm and 3.50-7.25 pieces (Bostan and Acar, 2009), 0.20-0.55 g, 7.46-10.59 mm, 3.84-5.58 mm and 3.5-10 pieces (Karadeniz et al., 2013), respectively. Findings are parallel to those of other researchers.

Fruit flesh firmness values varied between 2.40-7.00 kg/cm^2, while fruit taste took values between 2-5 (Table 1). Fruit flesh firmness has been reported as 9.46-10.33 kg/cm^2 (Karadeniz et al., 2013), 6.45-10.90 kg/cm^2 (Uzun et al., 2016), 6.27-9.39 kg/cm^2 (Şenyurt et al., 2015), 5.04-9.40 kg/cm^2 (Çöçen et al., 2019), 4.33-7.11 kg/cm^2 (Karataş, 2021). Fruit ripening is a complex process that includes flavor, color, cell wall changes and softening, starch degradation, and aroma development, and contributes significantly to distinctive fruit qualities (De Mori and Cipriani, 2023). Fruit firmness is one of the most important quality characteristics in consumer preferences, and fruit firmness may vary depending on variety, location, and environmental factors (Kumar et al., 2018). This research findings are similar to the results of other researchers regarding fruit flesh firmness.

Fruit color values of the genotypes were measured as L*, a*, b*, Chroma*, and hue° values between 29.08-74.70, 7.09-38.50, 7.51-44.19, 13.60-45.83, respectively. The coefficients of variation of the fruit color values generally gave high values for the examined traits and these values were determined as L* 22.99%, a* 35.47%, b* 46.41, Chroma* 25.69% and hue° 49.39% (Table 1). . Özmen and Çekiç (2021) reported L* 42.31-79.96, a* 21.91-27.47, and b* values between 20.79-45.22. In addition to genetic and transcriptional regulation, environmental factors such as light, temperature, water, sugars, plant hormones, and anthocyanin biosynthesis may also be effective in the formation of color in apples (Chen et al., 2021).

The results of the heatmap hierarchical clustering analysis showing how apple genotypes are grouped according to their similarities are given in Figure 2. The heatmap shows the similarities and differences between the samples and the examined traits with a color scale. Red tones represent high values, and blue tones represent low values. The figure shows that 17 apple genotypes are clearly divided into different clusters. G3 and G13 genotypes (marked in green) form a separate cluster from the other genotypes, showing high values especially in fruit weight, fruit length, and color parameters (L*, b*, Hue°, Chroma). Regarding SSC, the G3 genotype differs from all genotypes, especially from the G9 genotype. Indeed, (Mir et al., 2017) reported a similar situation. Within the main cluster, G1, G12, G16, G7, G14, G8 and G2 genotypes form a subcluster; The genotypes G4, G6, G9, G10, G11, G5, G17 and G15 form another sub-cluster. It is observed that the genotypes show significant differences, especially in the seed number, TA, and a* parameters. The clustering between the traits in the lower part of the dendrogram shows that the fruit traits (weight, length, width) and color parameters (L*, b*, Hue°, Chroma) are closely related.

PCA analysis provides essential information about which traits can be evaluated together in breeding programs while determining the selection criteria of genotypes within populations. Principal Component Analysis (PCA) results effectively reveal the variation in pomological and biochemical traits of the examined apple genotypes. The first five principal components (PC) explain 80.09% of the total variation (Table 2). PC1 is the most effective component with 26.61% variation and has positive loadings, especially on color parameters (L*, b*, Chroma*, and Hue°) and fruit sizes (weight, length, and width). PC2 represents 19.92% variation and shows positive loadings on fruit weight, fruit width, and taste parameters, as well as negative loadings on the flesh firmness parameter. When the relationships between genotypes and traits distributed on PC1 and PC2 axes are examined in the biplot graph, G3 and G13 genotypes stand out with positive values on the PC1 axis. In contrast, G6, G10, and G4 genotypes differ on the PC2 axis (Figure 2). The close positioning of fruit width, weight, and length vectors shows that these traits are strongly correlated. While color parameters (L*, b*, Hue°) are positively grouped on the PC1 axis, fruit flesh firmness is negatively prominent on the PC2 axis. Similarly, Mir et al. (2017) reported that the first component is related to fruit color, while SSC values are related to the fourth component.

Table 1. Descriptive statistics of apple genotypes in terms of examined traits.

Traits	Min.	Max.	Mean	±Std Dev	CV%
Fruit weight (g)	29.06	126.30	58.21	21.41	36.78
Fruit length (mm)	32.38	60.35	47.00	5.85	12.44
Fruit width (mm)	30.55	74.00	49.73	7.51	15.10
Seed number (pieces)	1.00	10.00	5.69	2.69	47.31
Seed weight (g)	0.12	0.55	0.30	0.12	39.48
Seed length (mm)	6.07	9.38	7.74	0.69	8.92
Seed width (mm)	2.71	5.41	4.14	0.50	12.04
SSC (%)	12.00	18.21	15.32	1.79	11.66
pH	2.93	5.30	4.05	0.59	14.45
TA (%)	0.17	1.88	0.63	0.44	69.68
Taste	2.00	5.00	3.59	0.87	24.25
Fruit flesh firmness (kg/cm^2)	2.40	7.00	5.15	0.96	18.61
Fruit colour L*	29.08	74.70	49.45	11.37	22.99
Fruit colour a*	7.09	38.50	20.88	7.41	35.47
Fruit colour b*	7.51	44.19	20.49	9.51	46.41
Fruit colour Chroma*	13.60	45.83	30.46	7.82	25.69
Fruit colour Hue°	14.11	108.45	44.21	21.83	49.39

Table 2. Eigenvalues, total variance ratios, and eigenvectors of principal components for the studied apple genotypes.

Traits	PC1	PC2	PC3	PC4	PC5
Fruit weight (g)	0.24	0.42	0.14	0.00	0.12
Fruit length (mm)	0.24	0.26	0.35	-0.07	0.04
Fruit width (mm)	0.25	0.43	0.08	-0.01	0.13
Seed number (pieces)	-0.24	-0.07	0.27	-0.09	-0.15
Seed weight (g)	-0.06	0.21	-0.47	0.17	-0.06
Seed length (mm)	-0.01	0.31	-0.26	-0.05	-0.23
Seed width (mm)	0.12	0.09	0.13	-0.22	0.53
SSC (%)	0.14	-0.16	-0.24	0.01	0.55
pH	0.01	-0.11	0.15	-0.58	-0.10
TA (%)	0.05	0.05	0.18	0.64	-0.08
Taste	-0.23	0.32	-0.08	0.06	0.32
Fruit flesh firmness (kg/cm²)	-0.04	-0.36	-0.27	0.07	0.32
Fruit colour L*	0.38	-0.19	-0.09	-0.20	-0.13
Fruit colour a*	-0.20	-0.18	0.43	0.23	0.15
Fruit colour b*	0.43	-0.17	-0.03	0.10	-0.06
Fruit colour Chroma*	0.36	-0.22	0.22	0.21	0.05
Fruit colour Hue°	0.42	-0.02	-0.18	0.07	-0.19
Eigenvalue	4.52	3.39	2.26	1.80	1.65
% of Variance	26.61	19.92	13.31	10.57	9.68
Cumulative %	26.61	46.53	59.84	70.41	80.09

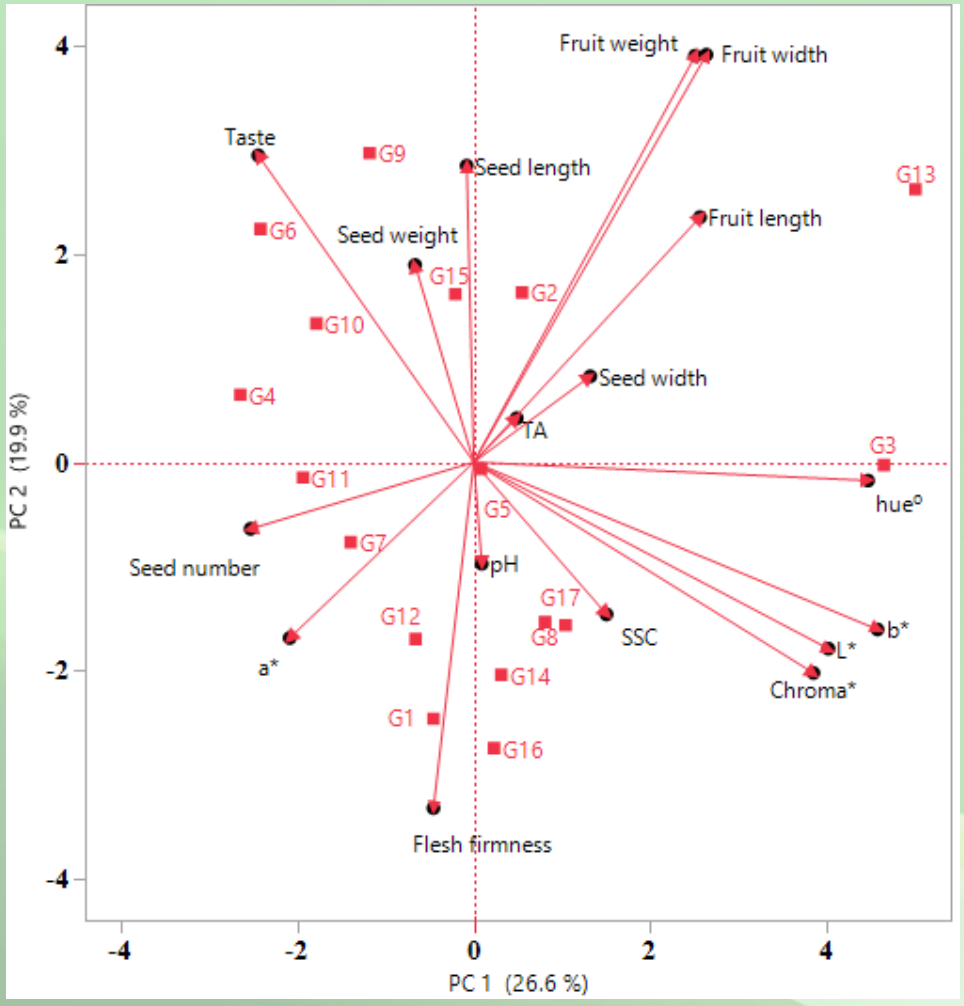


Figure 1. PCA analysis of the examined traits and genotypes

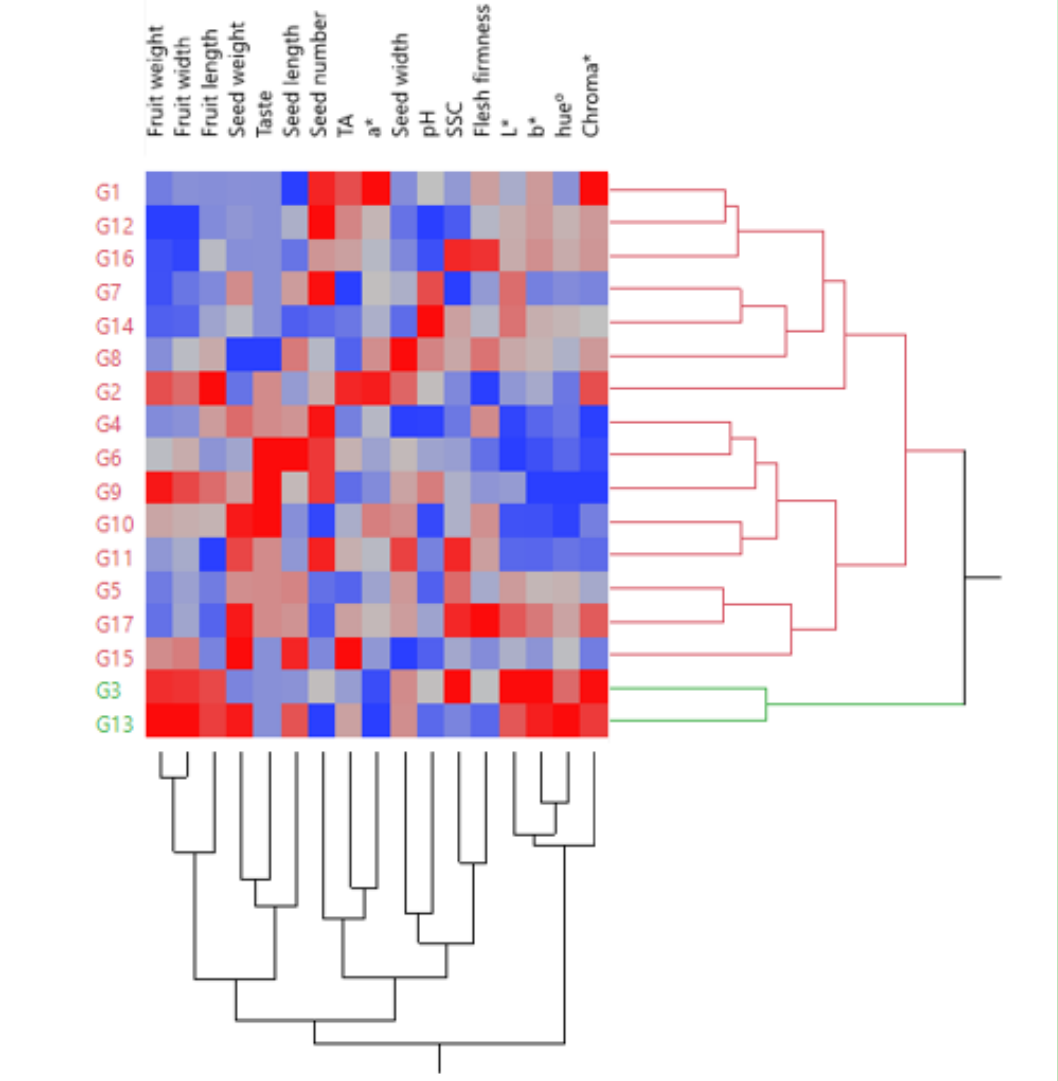


Figure 2. Hierarchical clustering analysis of apple genotypes and traits

Conclusion

This research investigated the pomological and biochemical properties of 17 apple genotypes collected from the Mudurnu/Bolu region. The research results revealed significant variation among the examined apple genotypes. A wide variation was observed in fruit weight (29.06-126.30 g), fruit length (32.38-60.35 mm), fruit width (30.55-74.00 mm), SSC (12.00-18.21%), pH (2.93-5.30), TA (0.17-1.88%) and fruit flesh firmness (2.40-7.00 kg/cm²) values. TA (69.68%) and color parameters (Hue° 49.39%, b* 46.41%) especially attracted attention due to their high coefficients of variation. According to PCA results, the first five components explained 80.09% of the total variation, PC1 (26.61%) was found to be effective especially on color parameters and fruit sizes, and PC2 (19.92%) was found to be effective on fruit weight, width, and taste. Hierarchical cluster analysis revealed that G3 and G13 genotypes were separated from other genotypes and showed superior characteristics, especially in fruit weight, length, and color parameters. Strong relationships were determined between fruit characteristics and color parameters. This research has made significant contributions to the characterization of apple genetic resources in the Mudurnu region, and the superior genotypes (especially G3 and G13) can be considered as parents in future breeding studies. In addition, the trait groups determined as a result of PCA and cluster analysis provide essential information on which traits can be evaluated together while establishing selection criteria in apple breeding programs. As a result, this study has provided valuable data for protecting, evaluating, and using regional apple genetic resources in breeding programs.

Conflict of interest statement

The authors declare that there is no conflict of interestregarding the publication of this paper.

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Biological Characterization of Tomato brown rugose fruit virus-Antalya Isolates

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Abstract

Tomato brown rugose fruit virus (ToBRFV, genus *Tobamovirus*) is a major pathogen of *Solanaceous* crops in the world. ToBRFV presents a significant and destructive threat to tomato and pepper plants. Türkiye, an important player in the global tomato supply chain, contributes approximately 13 million metric tons annually, ranking it third worldwide in production volume, following China and India. The majority of the production takes place under greenhouse conditions in the Mediterranean Region of Türkiye. Noteworthy, Antalya, Bursa, and Manisa provinces emerged as the foremost tomato-producing regions in 2023. Therefore, the virus inoculum sources used in this study were obtained from Antalya province. The main objective of this study was to investigate ToBRFV symptom characterization in host plants. For this purpose, in 2024, tomato and pepper varieties were mechanically inoculated with ToBRFV, and disease severity was assessed using a standardized disease severity index. In order to establish a control group, mock inoculated plants were used for each variety. The results revealed that some varieties exhibited severe symptoms, while others showed moderate symptoms, and one variety exhibited only mild symptoms. Based on these symptoms, some varieties are considered to be highly susceptible, others are susceptible and one shows tolerance. A key strategy for management of viral diseases is the development and deployment of resistant cultivars, for which disease epidemiology is crucial.

Key Words: *Tobamovirus fructirugosum, tomato, pepper, mechanical inoculation, disease severity index*

Introduction

The cultivated tomato, *Solanum lycopersicum* belongs to the *Solanaceae* family, a taxon of considerable global economic and agricultural significance. Tomatoes represent a substantial dietary source of essential micronutrients, notably vitamins C and E, the carotenoid lycopene (constituting approximately 80% of total carotenoids), folate, and various flavonoids (Willcox et al., 2003). The substantial nutritional value of tomatoes, attributed to their rich vitamin content and inherent antioxidant properties, underscores their status as a globally significant horticultural crop (Viuda-Martos et al., 2014). Specifically, lycopene, a red carotenoid pigment prevalent in tomatoes and processed products like ketchup, has been quantified in the range of 9.9–13.44 mg per 100 g (Story et al., 2013). This carotenoid contributes significantly to the antioxidant capacity and potential health benefits associated with tomato consumption. According to data released by the Food and Agriculture Organization of the United Nations (FAO) in 2023, the annual global tomato production reached approximately 186 million metric tons. Türkiye, a key player in the global tomato supply chain, contributes approximately 13 million metric tons annually, ranking it third worldwide in production volume, following China and India (TÜİK, 2023).

Tomatoes are cultivated in either small or large quantities across numerous regions of Türkiye. The majority of the production takes place under greenhouse conditions in the Mediterranean Region, particularly in Antalya. The other significant tomato-producing regions within Türkiye include the Aegean and Marmara regions. Noteworthy, in 2023, Antalya, Bursa, and Manisa provinces emerged as the foremost tomato-producing regions. Mersin, Çanakkale, Muğla, Tokat, and Çanakkale are significant provinces where tomato production is focused on table tomatoes. A substantial portion of the production in Izmir, Manisa, Balıkesir, and Şanlıurfa is evaluated in the production of tomato sauce.

Tomato cultivation is persistently challenged by a variety of pests and pathogens, among which viruses represent a significant threat to production. Prominent viral pathogens affecting tomatoes include cucumoviruses, tospoviruses, begomoviruses, potyviruses, and tobamoviruses. Among these, the Tobamovirus genus holds particular significance, as it encompasses several highly destructive pathogens such as tomato mosaic virus (ToMV), cucumber green mottle mosaic virus (CGMMV), tobacco mosaic virus (TMV), pepper mild mottle virus (PMMoV), and tomato mild mottle virus (ToMMV). Recently, tomato brown rugose fruit virus= Tobamovirus fructirugosum (ToBRFV) has emerged as a rapidly spreading RNA virus, primarily targeting peppers and tomatoes, with tomatoes being its primary host.

In tomatoes, ToBRFV infection is characterized by mosaic patterns, dark green blistering, yellow mottling, and leaf deformation, and narrowing of the leaves. Affected fruits exhibit yellow blotches, necrotic spotted, and brown rugose or wrinkled patches often resulting in loss of fruit yield (Salem et al., 2023). While tomato and pepper are

recognized as primary natural hosts, ToBRFV exhibits a broader host range. Experimental inoculation has demonstrated symptomatic infection in *N. glutinosa*, *N. tabacum*, *N. benthamiana*, and *N. sylvestris*. Furthermore, the observation of ToBRFV symptoms in weed species, such as *Solanum nigrum* and *Chenopodiastrum murale*, suggests their potential role as viral reservoirs, facilitating the persistence and spread of ToBRFV (EPPO, 2020).
ToBRFV is noted as a seed-borne virus, with contaminated seeds serving as the primary vector for long-distance dissemination. While mechanical contact facilitates short-distance spread, long-distance transmission occurs predominantly through infected seeds and fruits. The agricultural workers' hands, tools, shoes, and clothes can mechanically spread the virus, as well as plant-to-plant contact between infected and healthy plants (Salem et al., 2016). ToBRFV-infected plants exhibited 100% contamination from the seeds of tomatoes harvested. But just externally on the seed coat of tomato, ToBRFV was determined. Transmission appeared at a low rate from seed to seedling from the contaminated seeds. However, no evidence currently supports transmission by arthropod vectors. The Bombus terrestris (bumblebee) beneficial pollinator can carry away the primary inoculum of ToBRFV, thereby promoting the spread of ToBRFV in tomato crops cultivated in glasshouses or net houses (Dombrovsky et al., 2017; Levitzky et al., 2019).
ToBRFV has been listed in quarantine status in the European Union (EU) countries. Since there is no chemical control in viral diseases, the disease has gained even more importance. ToBRFV management is prevention of infection, hygiene, phytosanitary measures, host resistance, disinfection, biocontrol, and gene editing (Salem et al., 2023). Moreover, ToBRFV is one of the most new major virus diseases in tomato plants in our country. Therefore, the main purpose of this study is characterization of symptoms on tomato varieties and pepper.

Materials and Methods

Materials

This study evaluated the performance of five tomato (*Solanum lycopersicum*) varieties, one pepper (*Capsicum annuum*) variety and one wild-type tomato accession *Solanum pimpinellifolium* (LA1651-used as a control). Commercially available tomato varieties included Rio Grande, H2274, and Pintek. The local tomato and pepper cultivars were “Sazlıca tomato” and “Bor pepper”. Pintek and *S. pimpinellifolium* (LA1651) were specifically included due to their reported resistance or tolerance levels to ToBRFV. ToBRFV-infected tomato plant material, used as the inoculum source, was obtained from the T.R. Ministry of Agriculture and Forestry Plant Health Department, Batı Akdeniz Agricultural Research Institute (BATEM). The experiments were conducted within the controlled greenhouse environment and virology laboratory of the Department of Plant Production and Technologies, Niğde, Türkiye.

Methods

Experimental design

Given the highly contagious and deleterious nature of ToBRFV, this research was conducted in the controlled environment of a greenhouse at the Department of Plant Production and Technologies, Niğde Ömer Halisdemir University, Niğde, Türkiye, during the summer of 2024. The recorded highest average temperature was 35°C, while the lowest was 25°C throughout the summer season. The entire process was conducted between May and August. During this period, the average night temperature was 18°C, and the average daytime temperature reached 27°C in the Niğde province.

Seed Germination

In 2024, the tomato and pepper seeds were sown in the seed viols and subsequently, they were allowed to germinate within the same viols. The each viols includes thirty two holes, and a total of seven seed viols were used for each variety. A total of two hundred ten tomato seeds were sown and each variety included thirty seeds and the pots were utilized for transplanting and a total thirty pots were used for each variety.

Seedling Transplanting

Tomato seedlings were transplanted into pots after the germination of seeds. The seed viols were filled with a mixture of perlite and peat in a ratio of 3:1 while 210 plastic pots were filled with soil and a mixture of peat and perlite (3:1), respectively. For each variety, 30 pots were used and pots contained a total of 150 tomato seedlings and 30 Bor pepper seedlings. Also, the were used total of 30 plants as a control. The tomato and pepper seedlings were irrigated before transplantation and the following day, they were transplanted into the pots. The pots were regulated and labelled according to their properties in order to facilitate identification and the tomatoes were irrigated daily.

Mechanical inoculations of tomato and pepper plants

Following the confirmation of ToBRFV infections on tomato and tobacco plants by symptomatic and molecular analyses, fresh tomato leaves were utilized as an inoculum source for mechanical inoculations on both tomatoes and pepper plants. The leaf samples were manually ground with an inoculation buffer (pH: 7.4) consisting of 1.14 g/l Na_2HPO_4, 0.199 g/l KH_2PO_4, 1% PVP-40, and 0.1% Na_2SO_3. The inoculation was conducted on June 2024. Reinoculations were done after 10-14 days. In order to established a control group mock inoculated plants were used for each variety. The symptoms exhibited by tomato and pepper plants were observed 10 days after the mechanical inoculation and symptoms were monitored for 4 weeks for disease severity index evaluation.

Disease Severity Index (DSI) Evaluation

Following a 30-day period after mechanical inoculation, the severity of ToBRFV symptoms was evaluated using a modified disease severity index (DSI). The evaluation of plant symptoms was conducted in accordance with the 0 to 3 scale reported by Zinger et al. (2021). The DSI employed a 0-3 scale to visually assess symptom development in the inoculated plants. Alongside the DSI assessment, the percentage of ToBRFV-infected plants was also determined. DSI values were then calculated using the formulas (Figure 1) (Kabas et al., 2021; Chiang et al., 2017).

$$DSI(\%) = \frac{\text{Class frequency x score of rating class}}{\text{(Total number of observations) x(Maximal disease index)}} \times 100$$

Figure 1 . Disease severity index formulas

Results and Discussion

Virus Symptom Observations on Inoculated Plants

The study includes a total plant of 150 tomatoes and 30 pepper plants inoculated with ToBRFV on May under greenhouse conditions. All inoculated plants showed ToBRFV symptoms and were mostly observed on the leaves of the plant. The onset of symptoms was observed between 10 and 15 days following inoculation and the most common symptoms included mosaic of dark and light green, chlorotic, blistering, narrowing, leaf curling, and mottling observed on tomato and pepper plants.

H2274 and Pintek tomato varieties showed the same symptoms like malformation and deformation of leaves, narrowing, blistering, and very severe mosaic and mottling symptoms on leaves. Sazlıca and Rio Grande tomato varieties showed similar symptoms such as severe mosaic and yellow or green spotting, blistering, and upward curling edges of leaves. Moreover, Bor pepper variety showed symptoms such as mild mosaic and narrowing symptoms of leaves. In addition, the wild type of tomato (*S. pimpinellifolium*) showed symptoms very mild mosaic and mottling symptoms (Figure 2).

ToBRFV -Disease Severity Indices of tested plants

To demonstrate the impact of ToBRFV on tomato and pepper plants, a scale was constituted by ranking the plants from mild to severe (0 to 3). When creating the disease severity scale, the plant exhibiting the least symptoms was assigned a value of 1, while the plant exhibiting the most symptoms was assigned a value of 3. The plant disease value 1 was selected from infected plants with slight chlorosis, and mosaic form on leaves. Plant disease value 2 was selected from infected plants with severe mosaic form and blistering on leaves. Plant disease value 3 was selected from infected plants with very severe leaf narrowing, blistering on the leaf and wilt. This score rate is intraspecific and interspecific of varieties.

Moreover, to evaluated and determined H2274, Pintek, Sazlıca and Rio Grande tomato varieities symptom score value was 3 and Pintek, Sazlıca, Rio Grande, Bor pepper and *S. pimpinellifolium* tomato vaieities symptom score value was 2 also just bor pepper and *S.pimpinellifolium* varieties symptom score value was 1 after the thirty days of inoculation (Figure 3).

Furthermore, the highest infection value was observed in H2274 tomatoes, with a 100% rate, followed by Pintek varieties at 93.3%. In contrast, the wild type of tomato variety (*S.pimpinellifolium*) development the lowest infection rate of with 70% (Table 1).

The objective of this study was to characterize symptoms of ToBRFV on tomato and pepper varieties. Characteristic symptoms were included leaf deformation, mosaic patterns, green or yellow mottling, and leaf narrowing. Symptom onset occurred between 5 to 10 and 15 days post-inoculation. These findings are consistent with those reported by Salem et al. (2023), who observed similar symptoms of leaf mottling, mosaic, and narrowing in tomato plants infected with ToBRFV. Further, in the H2274 and Pintek tomato varieties, we observed symptoms such as leaf malformation, deformation, narrowing, leaf deformation, and severe mosaic and mottling. In the Sazlıca and Rio Grande varieties, severe mosaic, yellow or green spotting, leaf deformation, and upward leaf curling were prominent. Interestingly, milder symptoms, including mild mosaic and leaf narrowing, were observed in the wild-type tomato (*S. pimpinellifolium*) and Bor pepper varieties. Furthermore, Jewehan et al. (2021) reported that they observed very mild mosaic symptoms in *S. pimpinellifolium* tomatoes or no symptoms similar to those in this study.

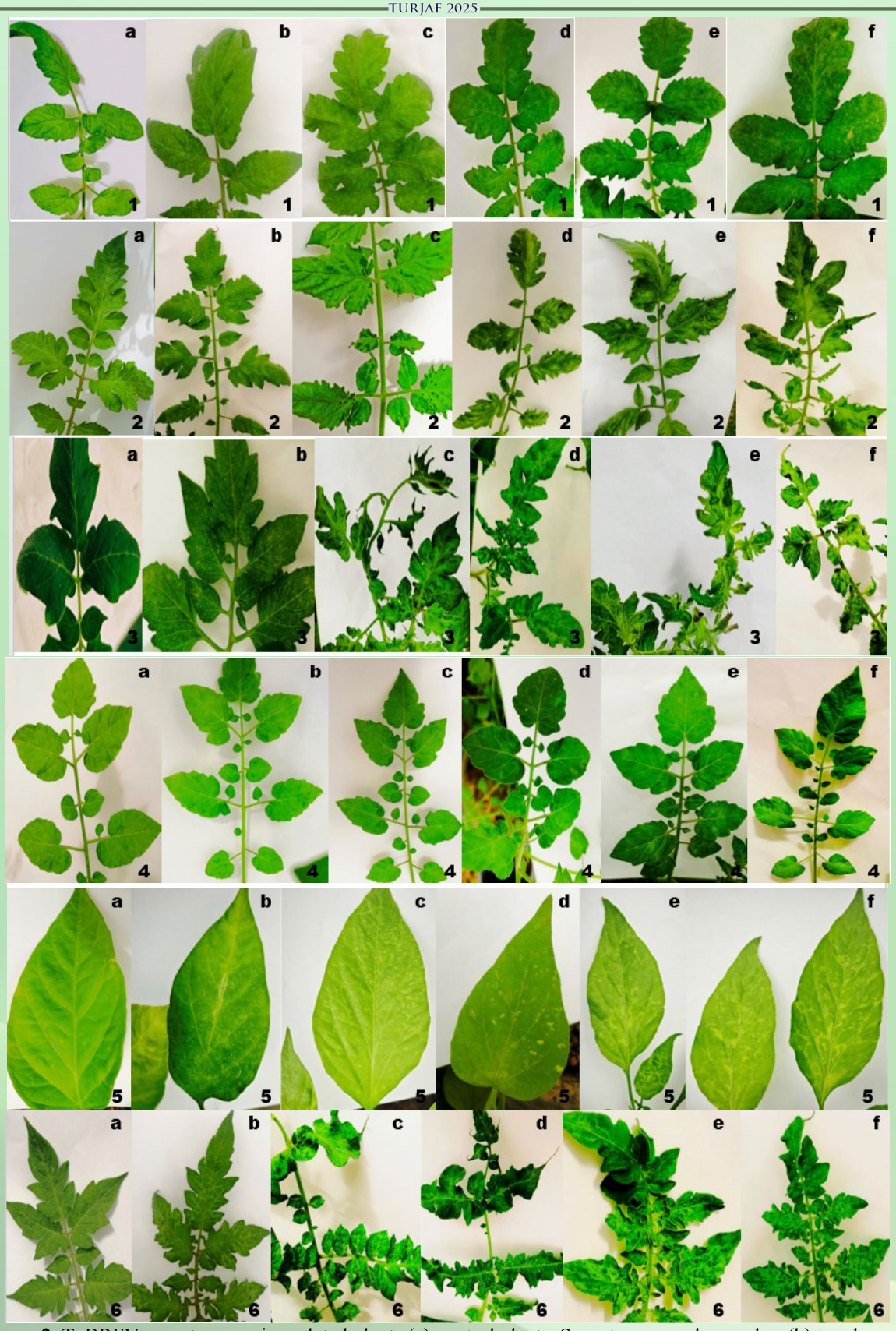


Figure 2. ToBRFV symptoms on inoculated plants (a) control plants, Symptoms are observed as (b) ten days, (c) fifteen days, (d) twenty days, (e) twenty five days and (f) thirty days after the mechanical inoculation. The plant numbers 1 was Rio Grande variety, 2 was Pintek variety, 3 was H2274 variety, 4 was wild type of tomato *S.pimpinellifolium*, 5 was Bor pepper variety and 6 was Sazlıca tomato variety.



Figure 3. Disease severity scales of tested varieties (a) all H2274 tomato score rate is 3, (b) Rio Grande varieties of right pot score rate is 3 and left pot score rate is 2, (c) Pintek varieties of right pot score rate is 3 and left pot score rate is 2, (d) Sazlıca varieties of right pot score rate is 3 and left pot score rate is 2, (e)Bor pepper varieties of right pot score rate is 2 and left pot score rate is 1, (f) wild type of tomato (*S. pimpinellifolium*) varieties of right pot score rate is 2 and left pot score rate is 1.

Additionally, the study focused on disease severity index of ToBRFV infected tomato and pepper plants, including disease infection rate of the plants. To assess the impact of ToBRFV on tomato and pepper plants, disease symptoms were monitored at 10, 15, 20, 25, and 30 days post-mechanical inoculation. A disease severity index was developed to quantify the severity of infection. A scale from 0 to 3 was employed, where 0 represented no

symptoms and 3 indicated the most severe symptoms. Disease severity was assessed at 30 days post-inoculation and the highest infection rate (100%) was observed in H2274 tomatoes, followed by Pintek (93.3%), Bor pepper (85%), and Sazlıca (83%). Rio Grande exhibited a 73% infection rate. In contrast, the wild-type tomato variety *S. pimpinellifolium* (LA1651) displayed the lowest infection rate (70%). These findings align with previous research by Kabas et al. (2022), who reported infection rates ranging from 38% to 60% in two *S. pimpinellifolium* accessions (LA1579 and LA0442).

A comprehensive ToBRFV management plan integrates multiple approaches such as prevention of initial infection, rigorous hygiene practices, utilizing host plant resistance where available, regular disinfection, exploring potential biocontrol agents, and investigating advanced techniques like gene editing for enhanced resistance.

Table 1. Disease severity classes of inoculated plants

Plant	Score number 3 (Highly Susceptible)	Score number 2 (Susceptible)	Score number 1 (Tolerant)	Score number 0 (Resistant)	Disease severity (%)
H2274	30	-	-	-	100
Pintek	24	6	-	-	93.3
Bor pepper	-	21	9	-	85
Sazlıca tomato	15	15	-	-	83.3
Rio Grande	6	24	-	-	73.3
S. pimpinellifolium	-	12	18	-	70

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Molecular Characterization of Tomato brown rugose fruit virus-Isparta Isolates Movement Protein

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Abstract

Tomato brown rugose fruit virus (ToBRFV; genus Tobamovirus) poses a significant threat to plants belonging to the Solanaceae family, especially tomato and pepper. ToBRFV is rapidly spreading worldwide and threatens global tomato production. This virus is transmitted mechanically or via seeds during agricultural activities. Therefore, effective methods and resistance genes are needed to control ToBRFV and other tobamoviruses. The aim of this study is to characterize the movement protein, which is an important gene region in the transmission, spread and resistance of the virus, by molecular methods. For this purpose, in this study, tomato seedlings showing disease symptoms were collected from tomato greenhouses in Isparta province in the summer of 2023 upon the complaints of the producers and 5 seedling samples from 14 different greenhouses (70 seedlings in total) were tested for the presence of the virus. Mechanical inoculations were done to susceptible tomato varieties using the provided plant leaves and disease symptoms were observed. Nucleic acid isolations were made from plant leaves and cDNA was synthesized. PCR analyses were performed using primer sequences of the virus-specific movement protein and the obtained PCR bands were subjected to DNA sequence analysis. The obtained nucleotide sequences were analyzed in the NCBI database and BLASTn analyses proved the existence of the virus. In addition, alignment of the obtained nucleotide sequences was performed with CLUSTAL W and the neighbor-joining method was used to create a phylogenetic tree with the MEGA11 program. It is thought that the findings will guide the fight against the disease.

Key Words: *tomato, ToBRFV, Mp protein, PCR, phylogenetic.*

Domates Kahverengi Buruşuk Meyve Virüsü- Isparta izolatlarının Hareket Proteininin Moleküler Karakterizasyonu

Özet

Domates kahverengi buruşuk meyve virüsü (ToBRFV) özellikle domates ve biber olmak üzere Solanaceae familyasına ait bitkilerde önemli bir sorun oluşturmaktadır. ToBRFV dünya çapında hızla yayılmakta ve küresel çapta domates üretimini tehdit etmektedir. Bu virüs, tarımsal faaliyetler sırasında mekanik olarak veya tohumlar yoluyla bulaşmaktadır. Bu nedenle, ToBRFV ve diğer tobamovirüsleri kontrol etmek için etkili yöntemlere ve dayanıklılık genlerine ihtiyaç duyulmaktadır. Bu çalışmanın amacı, virüsün bulaşması, yayılması ve dayanıklılığında önemli bir gen bölgesi olan hareket proteininin (movement protein) moleküler yöntemler aracılığıyla karakterize edilmesidir. Bu amaçla, bu çalışmada 2023 yılının yaz aylarında Isparta ili domates seralarından üreticilerin şikâyeti üzerine hastalık belirtileri gösteren domates fideleri toplanmış ve 14 farklı seradan alınan 5'er fide örneği (toplam 70 fide) virüs varlığı açısından test edilmiştir. Temin edilen bitki yaprakları kullanılarak hassas domates çeşidine mekanik inokulasyonlar yapılmış ve hastalık simptomları gözlenmiştir. Bitki yapraklarından nükleik asit izolasyonları yapılmış ve cDNA sentez edilmiştir. Virüse özgü hareket proteine ait primer dizileri kullanılarak PCR analizleri yapılmış ve elde edilen PCR bantları DNA dizi analizine tabii tutulmuştur. Temin edilen nükleotid dizileri NCBI veritabanında analiz edilmiş ve BLASTn analizleri virüsün varlığını kanıtlamıştır. Ayrıca elde edilen nükleotid dizilerinin hizalanması CLUSTAL W ile gerçekleştirilmiş ve MEGA11 programı ile filogenetik ağaç oluşturmak için neighbor-joining yöntemi kullanılmıştır. Bulguların, hastalık ile mücadelede yol gösterici olacağı düşünülmektedir.

Anahtar Kelimeler: *Domates, ToBRFV, Mp proteini, PCR, filogenetik*

Giriş

Domates kahverengi buruşuk meyve virüsü (Tomato brown rugose fruit virus: ToBRFV) özellikle domates başta olmak üzere Solanaceae (patlıcangiller) familyasına ait bitkilerde önemli bir tehdit oluşturan virüstür. ToBRFV, 2014'ün sonlarında İsrail'de keşfedilmiştir. 2015 yılında İsrail'in domates yetiştirilen Melilot, Beit Ezra ve Achituv

alanlarına yayılmıştır. İlk olarak 2016 yılında Ürdün'de rapor edilmiştir (Salem ve diğerleri, 2016). Virüs İsrail'de bir yıl içerisinde neredeyse ülke çapında domates seralarına yayılmıştır. ToBRFV dünya çapında hızla yayılmakta ve küresel domates üretimini tehdit etmektedir. Bu virüs, tarımsal faaliyetler sırasında mekanik olarak veya tohum yoluyla bulaşmaktadırlar (Dombrovsky ve diğerleri, 2017). Bu nedenle, ToBRFV ve diğer tobamovirüsleri kontrol etmek için etkili ve dayanıklılık genlerine ihtiyaç duyulmaktadır.

Virüs enfeksiyon oluşturduğu domates bitkilerinde şiddetli simptomlara neden olur. Hastalık domates yapraklarında mozaikleşme, klorozis, benek şeklinde lekelenme ile ileri dönemlerde nekrotik dokular ve cüceliğe ve sonunda da bitki ölümüne neden olmaktadır. Meyvelerde ise kahverengi lekeler ve buruşuk meyve oluşumu en temel simptomları arasında yer almaktadır (Salem ve diğerleri, 2016).

ToBRFV, uzun ve simetrik çubuksu yapıda virion yapısına sahiptir ve diğer Tobamovirüslerle benzerlik göstermektedir. ToBRFV genomu da diğer tobamovirüslerinkine çok benzerdir. Bu virüslerin genomu, dört açık okuma çerçevesi (ORF) içeren yaklaşık 6.400 nükleotid uzunluğunda tek zincirli pozitif anlamlı bir RNA molekülünden oluşmaktadır. Genomik RNA, CAA tekrarları açısından zengin kısa bir 5' çevrilmemiş bölge (UTR) ve psödoknotlara katlanabilen bir 3' UTR ile kapatılır ve bunu transfer RNA benzeri, amino asit olan bir yapı izlemektedir. İki 5' -terminal ORF doğrudan genomik RNA'dan çevrilir. ORF1, metiltransferaz ve helikaz alanları içeren 126 kDa'lık bir proteine (p126) çevrilir. ORF1 ve ORF2 arasındaki UAG durdurma kodonunun okunması, C-terminal ucunda RNA'ya bağımlı bir RNA polimeraz alanı içeren 183 kDa'lık bir proteinin (p183) ekspresyonuyla sonuçlanabilir. Her iki protein de replikasyon için gereklidir ve p126 ayrıca diğer tobamovirüslerde gösterildiği gibi bir susturma baskılayıcısı olarak işlev görmektedir. ORF3 ve ORF4, 3'- koterminal olan ve sırasıyla 30 kDa'lık bir hareket proteini (MP) ve 17,5 kDa'lık bir kılıf proteini (CP) kodlayan 5'- subgenomik RNA 1 ve 2' den çevrilir (Salem N. ve diğerleri, 2022).

Tobamovirüslerin enfeksiyon döngüsünde en önemli proteinlerden biri hareket proteinidir. Bu protein virüsün bitki içerisinde hareket etmesini sağlar. Virüs, enfekte ettiği hücre içerisinde çoğaldıktan sonra komşu hücrelere yayılmak zorundadır. Hareket proteinleri, virüs genomlarının hücreler arası kanallardan (plasmodesmata) geçerek komşu hücrelere taşınmasını kolaylaştırır. Ayrıca bitki hücresinin mikrotübüller ve aktin filamentleri ile etkileşime girerek virüsün hücre içindeki hareketini yönlendirir ve hızlandırır. Bazı hareket proteinleri, hücre duvarının geçirgenliğini artırarak virüsün hücreler arası geçişini kolaylaştırır. Hareket proteinleri, bitkinin savunma mekanizmalarını baskılayarak virüsün çoğalmasını ve yayılmasını sağlar. Hareket proteini sayesinde tobamovirüsler, enfekte ettikleri bitkinin tüm kısımlarına yayılarak sistemik bir enfeksiyona neden olurlar. Hareket proteininin etkinliği, hastalığın şiddeti ile doğrudan ilişkilidir. Daha etkin hareket proteinlerine sahip virüsler, daha hızlı ve daha geniş alanlara yayılarak bitkiye daha fazla zarar verir. Bununla birlikte, virüsün evrimi için önemli bir faktördür. Mutasyonlar sonucu oluşan yeni hareket proteinleri, virüse yeni konukçularına adapte olma ve daha etkili bir şekilde yayılma avantajı sağlamaktadır.

Bu çalışmanın amacı, Tobamovirus cinsinin hızla yayılmakta olan bu ToBRFV virüsünün bulaşması, yayılması ve dayanıklılığında önemli bir gen bölgesi olan hareket proteininin (movement protein) moleküler yöntemler aracılığıyla karakterize edilmesidir. Bu amaçla, hastalıklı bitki temin edilerek sağlıklı fideler inokule edilmiştir. Bitkilerden nükleik asit izole edilerek virüsün hareket proteini nükleotid düzeyinde moleküler olarak karakterize edilmiştir.

Materyal ve Yöntem

Virüs Kaynağı

Domates kahverengi rugose meyve virüsü (ToBRFV) kaynağı Isparta İlinde bulunan 14 farklı seralardan temin edilmiştir. Her bir seradan beşer adet bitki olmak üzere toplam olarak 70 bitki örneği temin edilmiş olup bu bitkiler şiddetli hastlık belirtisi içeren ve üreticilerin şikâyetleri üzerine toplanmıştır.

Mekanik İnokulasyonlar

Virus kaynağını çoğaltmak için mekanik inokulasyonlar yapılmıştır. Her bir serayı temsilen 14 adet hassas olduğu bilinen H2274 domates tohumları kullanılmış olup tohum ekimi, fide yetiştirme ve belirtileri gözlemleme işlemleri Niğde Ömer Halisdemir Üniversitesi Tarım Bilimleri ve Teknolojileri Fakültesi'ndeki Bitki Virolojisi bitki yetiştirme odasında gerçekleştirilmiştir. Domateslerin 4-5 yapraklı olduğu zaman mekanik inokulasyonu yapılmıştır. Mekanik inokülasyonlar için, 0.199 g/l KH_2PO_4, 1.14 g/l Na_2HPO_4 ve %0,1 Na_2SO_3 ve 1% PVP-40 içeren inokülasyon tampon çözeltisi (pH: 7.4) kullanılmıştır. Mekanik inokulasyon için fosfat solüsyonu içinde homojenize edilen virüs kaynağı yapraklara karborandum serpilmesi ile aşındırma sonucu yaprak yüzeyine sürülmüştür ve yarım saat sonra musluk suyu ile durulanmıştır. İnokülasyonu yapılan domates bitkileri, inokülasyondan bir ay sonra virüs enfeksiyonunu doğrulamak için PCR analizleri yapılmıştır.

Moleküler Analizler

Toplam NA Ekstraksiyonu

İnokulum kaynaklarındaki enfeksiyondan emin olabilmek için, toplam NA, üreticinin talimatlarını izleyerek domates yaprağı dokularından çıkarılmış ve saflaştırılmıştır. İnokule bitkiler ile inokulum kaynağını oluşturan bitkilerin (her bir seradan temin edilen beşer bitki karıştırılarak) yaprak dokularından NA ekstraksiyonu için hızlı ve etkili bir yöntem olan hızlı CTAB yöntemi (Gambino ve diğerleri, 2008) kullanılmıştır. Toplam NA'ların verimi ve kalitesi, bir BioSpec spektrofotometre (Shimatzu, ABD) kullanılarak ölçülmüştür.

cDNA Sentezi ve PCR Analizi

İki aşamalı bir RT-PCR protokolü kullanılmıştır. Birinci iplikçik cDNA, cDNA Sentez Kiti talimatları için rastgele heksamer primerleri ve Superscript Choice Sistemi kullanılarak toplam RNA'ların Ters transkripsiyonuyla sentezlenmiştir. PCR, 2 µl cDNA, 0,5 µl 10mM dNTP, 1 µl 25 mM $MgCl_2$, 2,5 µl 5X PCR tampon çözeltisi ve virüse spesifik primerlerden 0,5 µl 10 µM ve 0.25 µl 5 birim /µl Taq DNA polimerazı ile yapılmıştır. PCR, aşağıdaki koşullar altında gerçekleştirilmiştir: 94 °C'de 5 dakika denatürasyon, 30 saniye boyunca 94 °C'de, 45 saniye boyunca 55 °C'de ve 1 dakika boyunca 72 °C'de 40 döngü ve 72 °C'de 10 dakika boyunca son bir uzama. PCR ürünleri, %1,5 agarose jele yüklenip elektroforezde koşturulmuş ve bir UV-transillüminatör altında ethidium bromide ile uygulandıktan sonra UV ışığı altında incelenmiştir. ToBRFV MP geni için F- 5'-GATGGCTCTTGTTAAGGGTAAA-3' and R- 5'-CCCATGCTGATGACAAAAAC-3'-858 bp primer çifti kullanılmıştır (Güller A ve diğerleri., 2023).

Nükleotid Dizi Analizleri

PCR ürünlerinin nükleotid dizi analizleri, BMLabosis Firması (Ankara, Türkiye) ABI 3730 Automated Genetic Analyzer cihazı ile doğrudan dizilenmiştir. Nükleotidleri belirlemek için BLASTn ve BLASTx modülleri kullanılmıştır.

Filogenetik Analizler

GenBank'ta (NCBI) depolanan farklı izolatların dizileri hem nükletid hem de aminosit düzeyinde filogenetik analize alınmıştır. Nükleotid dizilerinin çoklu hizalaması CLUSTAL W ile gerçekleştirilmiş ve Molecular Evolutionary Genetics Analysis MEGA11 programı ile filogenetik ağaç oluşturmak için neighbor-joining yöntemi kullanılamıştır (Tamura ve diğerleri, 2011). Filogenetik ağaçların her bir düğümünün sağlamlığı, 1000 bootstrap kopyasından değerlendirilmiştir.

Bulgular ve Tartışma

Mekanik İnokulasyon Sonuçları

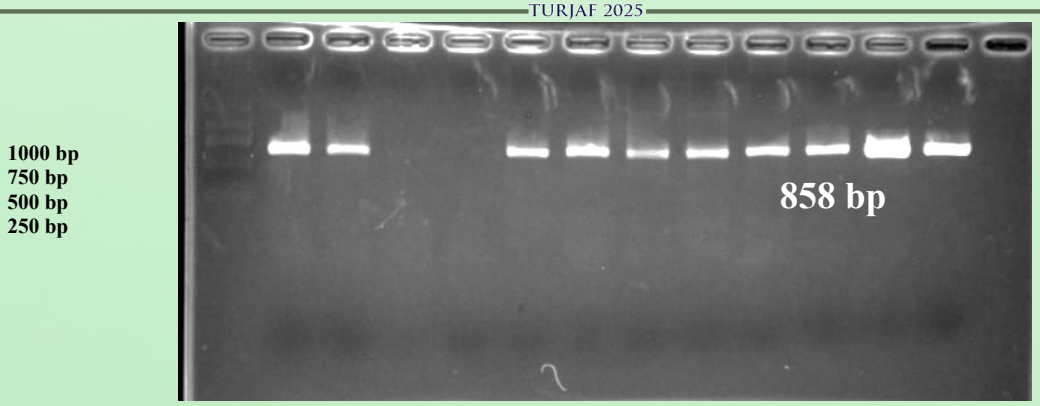
Yapılan inokulasyonlar sonrasında virüs simptomlarının çok hızlı görülmeye başlandığı gözlenmiştir. İnokulasyondan 5-7 gün sonra ilk belirtiler oluşmuştur. Belirtiler arasında en yaygın olanlar mozaikleşmeler olup yaprak kıvırcıklığı ve sarı benekler de yaygın olarak gözlenmiştir. Simptom gelişimleri bir ay boyunca gözlenmiştir. Virus simptomları yedinci gün, onuncu gün belirti vermiştir ve on beş, yirmi, yirmi beş ve otuz günün simptom gelişimleri incelenmiştir ve şiddetli virüs simptomları kaydedilmiştir. Yapraklarda şiddetli belirtiler örneğin yapraklarda mozaikleşme ve sarı renkte benek oluşumları ve kıvırcıklanmalar yaygındır.

Total NA İzolasyonu Sonuçları

CTAB yöntemine göre yapılan izolasyonlar sonucunda elde edilen nükleik asitlerin kalite değerleri nanodrop spektrofotometre cihazı aracılığıyla ölçülmüş olup 230/260 optik okuma değerleri elde edilmiştir. Bu değerlerin 1.5 ila 2-2 ng/ul arası olduğu tespit edilmiş olup bu değerlerin PCR analizleri için uygun kalitede olduğu görülmüştür. Optimum RNA saflığı 260/280 oranının yaklaşık 2,0 ve 260/230 oranının 2,0 ile 2,2 arasında olmasıyla gösterilir. pH bu oranları etkileyebilirken, yukarıdaki değerler 1.8 genellikle kabul edilebilir olarak değerlendirilmektedir.

RT-PCR Analiz sonuçları

Yapraklardan izole edilen virüs RNA'larının iki aşamalı cDNA sentezi yapılıp MP genine özgü primer çiftlerinin kullanılması ile ToBRFV'nin kısmi nükleotid dizileri çoğaltılmıştır. Testlenen tüm izolatlar beklenildiği gibi 858 bp'lik bant göstemiştir (Şekil 1).



Şekil 1: RT- PCR analizi sonucu agaroz jel görüntüsü, M: Thermo scientific 1 kb plus DNA Ladder

DNA Dizi Analizi Sonuçları

Elde edilen PCR ürünleri DNA dizi analizine alınmış olup 858 bp büyüklüğünde nükleotid dizileri elde edilmiştir. Bu dizilerin BLASTn analizleri yapılmış olup örneklerimizin Gen Bankasına kayıtlı örneklerle kıyaslandığında yakşalık olarak %98 ila 99,5 oranında benzerlik gösterdiği tespit edilmiştir.

Filogenetik Analiz Sonuçları

Nükleotid ve amino asit dizilerinin tanımlanması ve hizalanması, virüslerin genetik çeşitliliğini analiz etmek için yaygın olarak kullanılmaktadır (Nyalugwe ve diğerleri, 2015; Farzadfar ve Pourrahim, 2017). Isparta ToBRFV izolatının MP gen bölgesinin nükleotid ve amino asit dizileri, maksimum olabilirlik analizi kullanılarak NCBI veri tabanında halihazırda bulunan diğer gen dizileri ile filogenetik ilişkileri açısından karşılaştırılmış ve değerlendirilmiştir. Isparta ToBRFV izolatlarının genetik yapısı mevcut literatürle örtüşmekte, ancak aynı zamanda yeni bilgiler de ortaya koymaktadır.

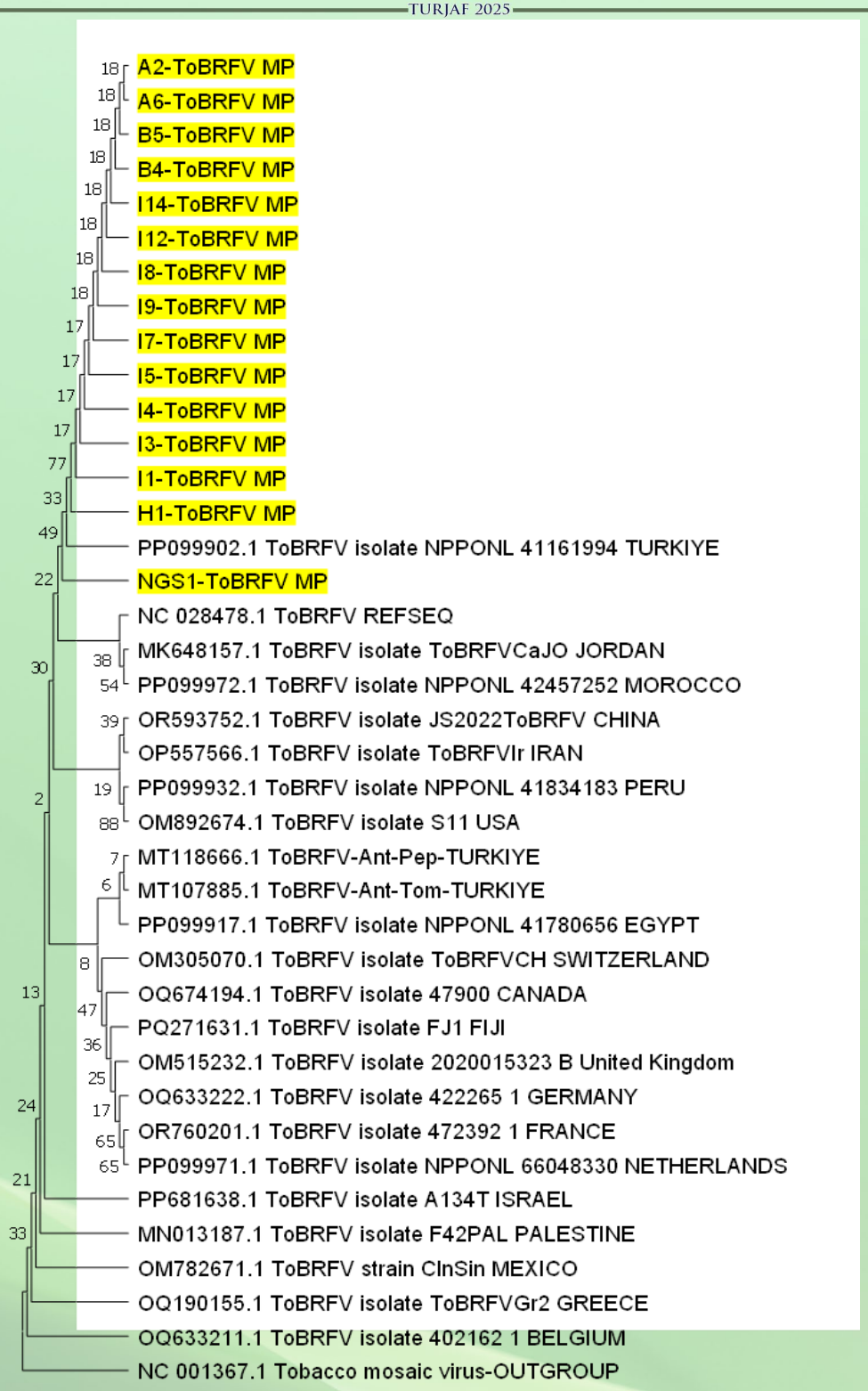
Kullandığımız Komşu Birleştirme Yönteminde kümelenme temelli algoritmada olduğu gibi taksonların kökten eşit uzaklıkta olduğu varsayılamaz. Yöntemimiz oldukça verimlidir ve geniş çapta verileri ve veri topluluklarını analiz etmeye yardımcı olur. Dış grup takson olarak incelenen organizma grubu TMV ise, evrimsel ilişkileri belirlerken daha uzaktan ilişkili olan ve referans grubu olarak kullanılan organizmalardır ve dış grup, iç grup için bir karşılaştırma noktası olarak kullanılır ve özel olarak da filogeninin kökünün olmasını sağlar.

Nükleotid dizileri ile oluşturulan MP gen bölgesi ağacında, Isparta izolatlarının birbiri ile çok benzer olduğu ve bu izolatların GenBankasına kayıtlı olan PP099902.1 numaralı NPPLONL41161994 nolu Türkiye izolatı ile yüksek oranda homoloji gösterdiği tespit edilmiştir (Şekil 2). Ayrıca Türkiye'den izole edilen Antalya örneklerinin de bizim izolatlarımız ile yakın bir dalda kümelendeği tespit edilmiştir (MT107885.1 ToBRFV-Ant-Tom-TURKIYE ile biberden izole edilen MT118666.1 ToBRFV-Ant-Pep-TURKIYE izolatı). Kontrol grubu olarak kullanılan Tütün mozaik virüsü ise beklendiği gibi en uzak dalda yer almaktadır.

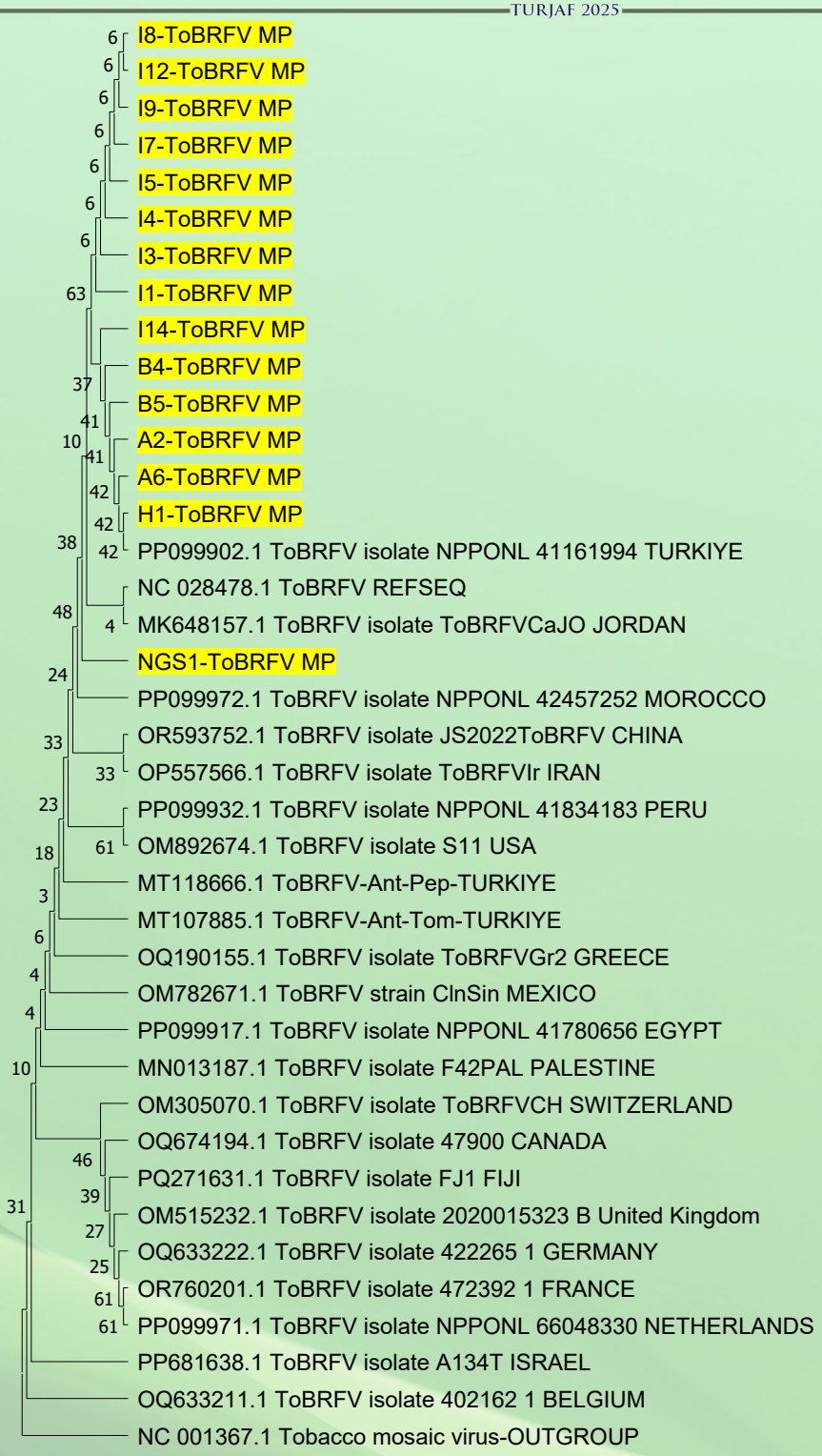
Virüsün nükleotid dizilerinin aminoasite çevrilmesi ile oluşturulan ağaç nükleotid ağacı ile benzer sonuçlar vermis olup farklı olarak MK648157.1 ToBRFV isolate ToBRFVCaJO JORDAN kodlu Ürdün izolatı da bizim örneklerimizle aynı grupta kümelenmiştir (Şekil 3). Tobamovirüslerin stabil yapısı dikkate alındığında bu sonuçların beklenildiği gibi olduğu düşünülmektedir.

Tüm elde edilen verilere dayanılarak; domates buruşuk meyve virüsünün hareket proteini moleküler karekterizasyonu yapılmış olup virüsün bu genindeki varyasyon moleküler olarak belirlenmiştir. Isparta ToBRFV izolatlarının genetik yapısı analiz edilmiş olup GenBankasındaki mevcut dizilerle yüksek oranda homoloji gösterdiği tespit edilmiştirr. Tobamovirüs enfeksiyon döngüsü için çok önemli olan bu hareket proteininin komşu hücrelere geçişi kolaylaştırdığı gibi bitkinin savunma mekanizmasını da baskılayarak virüsün yayılımını ve çoğalımını sağladığı bilinmektedir. Bu nedenle, elde edilen verilerle MP genininin çok fazla varyasyon içermediği ve taşınma kaynaklı mücadele yöntemlerine yardımcı olacağı düşünülmektedir.

ToBRFV tarımsal faaliyetler sırasında mekanik veya tohum yoluyla bulaşmaktadır. Bundan dolayı ToBRFV ve diğer tobamovirüsleri kontrol etmek için etkili ve dayanıklılık genlere ihtiyaç olduğu saptanmıştır. Bu dayanıklılık genlerin ve bitkilerin CRISPR\Cas9 en kısa en doğru genom düzenleme aracı ile üretilebileceği düşünülmekte olup bu yöntem ile ToBRFV dayanıklı domates yetiştiriciliği kolaylaşacağı düşünülmektedir.



Şekil 2: ToBRFV izolatlarının MP (movement protein) nükleotid dizilerinden MEGA11'de Komşu-Birleştirme yöntemi ile çıkarılan filogenetik ağacı. Bu çalışmadan elde edilen izolatlar sarı ile vurgulanmıştır. NGS1 izolatı iç kontrol izolatımızdır. İç düğümlerdeki sayılar, 1.000 tekrarlamaya dayalı bootstrap yüzdelerini göstermektedir. TMV izolatı dizileri dış grup taksonu olarak kullanılmıştır.



Şekil 3: ToBRFV izolatlarının MP (movement protein) aminoasit dizilerinden MEGA11'de Komşu-Birleştirme yöntemi ile çıkarılan filogenetik ağacı. Bu çalışmadan elde edilen izolatlar sarı ile vurgulanmıştır. NGS1 izolatı iç kontrol izolatımızdır. İç düğümlerdeki sayılar, 1.000 tekrarlamaya dayalı bootstrap yüzdelerini göstermektedir. TMV izolatının aa dizileri dış grup taksonu olarak kullanılmıştır.

Teşekkür
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Building Regenerative Agri-Net Zero Model: Bridging Corporate Responsibility and Farmers' Sustainability through Climate Action Strategies

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Abstract

Climate change is accelerating threats to global food and nutritional security, placing unprecedented strain on livelihoods of farming community. Intensifying biotic and abiotic stress are undermining crop productivity, while the soaring costs of cultivation compound the vulnerability of small and marginal farmers—the backbone of the agricultural workforce. Despite widespread recognition of these challenges, scalable, ecosystem-aligned technological interventions that are socially acceptable and economically viable remain elusive. Agri-Net Zero is a top climate action strategy that transforms agricultural landscapes into dynamic carbon sinks while directly reducing greenhouse gas emissions. By integrating regenerative practices with economic and social benefits, it not only drives net zero compliance but also enhances ecosystem resilience and rural livelihoods.

In response, the IBM-IORF Sustainability Accelerator initiative has piloted a climate-resilient Agri-Net Zero model across two agro-ecosystems in India by integrating Inhana Rational Farming (IRF)—a nature-based, regenerative farming framework. IRF eliminates chemical pesticide use, minimizes N fertilizer inputs, restores soil health and enhances plant resilience through targeted physiological interventions .

The outcomes of regenerative, coconut-based integrated farming systems are transformative: a 30% increase in crop yield, 20% improvement in nutrient use efficiency, up to a 60% transition to renewable energy use, 40% boost in farm income, 17% growth in rural employment, and carbon mitigation potential of up to 250 metric tons of CO_2e per hectare. These results, independently verified through third-party audit, led to India's first Agri-Net Zero certification by iNoCarbon, UK. Crucially, innovations such as coir pith recycling and nitrogen input optimization simultaneously advance soil carbon sequestration and reduce greenhouse gas emissions. This model presents a compelling case forcorporate Net Zero ambitions with the sustainability of farming communities, delivering measurable social and environmental co-benefits while directly addressing seven crucial UN Sustainable Development Goals (SDGs). Strategic investment in such regenerative transitions can empower farmers as pivotal actors in the global response to climate change.

Key Words : GHG mitigation, Soil health management, ACFA (version 2.0)

Introduction

Climate change is intensifying biotic and abiotic stresses on agriculture, directly threatening global food and nutritional security (Benitez-Alfonso et al., 2023). These escalating stresses reduce crop productivity and inflate cultivation costs, making climate-resilient, regenerative agricultural practices not only urgent but essential for future food systems (WEF, 2024). These practices—centered on soil and plant health—are key to adapting to climate shocks and mitigating their long-term impacts (Bera et al., 2025). However, small and marginal farmers—who constitute a majority of the global farming population—remain most vulnerable, lacking access to adaptive resources and technical capacity (Mazik et al., 2025).Simultaneously, the corporate sector faces increasing pressure to embed sustainability into operations to meet Net Zero targets and drive ESG commitments. Globally, nearly 9,000 companies have pledged emission reductions, with ~3,500 targeting net-zero. Europe leads with 2,998 companies; Asia follows with 1,846. The UK tops the list (702 firms), while China—despite being the largest global emitter—lags in corporate adoption. India ranks sixth with 127 companies committed to net-zero (ET Energy World, 2024). Bridging this corporate-agriculture divide is vital for achieving scalable, systemic climate action.

Agri-Net Zero emerges as a leading climate action strategy that transforms agricultural landscapes into dynamic carbon sinks, directly reducing greenhouse gas emissions. This innovative approach leverages regenerative practices to improve soil health and enhance biodiversity, positioning agriculture as a key player in net zero compliance. By integrating these sustainable farming methods, Agri-Net Zero not only mitigates emissions but also unlocks significant economic and social benefits for rural communities. Its comprehensive framework strengthens ecosystem resilience while bolstering rural livelihoods, reinforcing the critical role of agriculture in

the broader fight against climate change. Consequently, Agri-Net Zero stands as a transformative strategy, charting a pathway toward a more sustainable and climate-resilient future.

The Regenerative Agri–Net Zero Model offers a transformative pathway, enabling corporations to enhance ESG performance through measurable carbon mitigation alongside social and ecological co-benefits. Yet two persistent gaps hinder progress: the absence of a roadmap for sustainable agriculture, and the challenge of quantifying carbon mitigation, due to the lack of standardized tools tailored to farming (Guan et al., 2023).

For wide-scale success, this model must be climate-resilient, ecosystem-aligned, easily adoptable, financially viable, and scalable. Particularly in India, where over 80% of farmers are smallholders, risk-averse models are crucial. The model must avoid productivity losses while restoring soil–plant–ecosystem balance from the outset. This is achieved through two pillars: (1) a robust bioconversion technology to convert waste into compost—a scalable, low-cost solution for sustainable soil health; and (2) plant health management strategies that ensure smooth transitions from synthetic nitrogen to compost-based systems. Given that abrupt nitrogen reduction often leads to yield loss, targeted plant health practices can safeguard productivity and support nutrient sustainability.

This study documents the development and deployment of the Climate-Smart Agri–Net Zero model, highlighting its dual impact: empowering farmer resilience and accelerating corporate climate goals. It further incorporates ACFA (v2.0)—India's first carbon accounting standard for sustainable agriculture—to address the persistent challenge of carbon measurement (Gomage, 2024). Together, these innovations pave the way for regenerative agricultural transitions that align climate, community, and corporate goals—delivering a viable blueprint for a sustainable, net-zero food future.

Materials and method

Study Area : The study was initiated under IBM-IORF Sustainability Project during 2022-23 at Mandya District, Karnataka, India. The area belongs to hot, moist semiarid agro-ecological sub region 8.2 with medium to deep red loamy soils, low available water holding capacity (AWC) and length of Growing Period 120 – 150 days.

Coir Pith: A Persistent Landfill Hazard, Not Just Agro-Waste

Coir pith—a residue generated from coconut processing—deserves recognition as landfill waste rather than agro-waste due to its inherent recalcitrance and environmental risks. Its high lignin content and markedly imbalanced carbon-to-nitrogen ratio hinder microbial metabolism, resulting in exceedingly slow biodegradation. This persistent nature leads to prolonged accumulation in landfill sites, where coir pith becomes a significant source of methane emissions, a potent greenhouse gas (Rajalakshmi et al., 2018; Brebu & Vasile, 2010). Moreover, coir pith leachates are rich in bioactive compounds such as phenolics and tannins, which can disrupt soil microbial dynamics and nutrient cycling if inadvertently released into the environment (Singh & Patel, 2020; Khan et al., 2011). In light of these complexities and its limited capacity for rapid natural decomposition, coir pith should be reclassified as landfill waste. Such a reclassification would underscore the need for stringent waste management practices and innovative recycling strategies to mitigate its contribution to environmental pollution and methane emissions, aligning regulatory efforts with its true impact on ecological and human health (Kirchherr, Reike, & Hekkert, 2017; FAO, 2018). This new perspective calls for targeted regulatory interventions, as already suggested by agencies in India, including the Central Pollution Control Board and the Tamil Nadu Pollution Control Board, which recognize the severe challenges posed by improperly managed coir pith in landfill settings (CPCB, 2016; TNPCB, 2020; Devanathan, 2021).

Clean Food Net Zero Program: Coconut-Based Circular Economy Model

Under the IBM-IORF Sustainability Project (2021–22 to 2023–24), a comprehensive coconut-based intercropping model was developed to enhance crop diversity and improve farm productivity on marginal soils by integrating Inhana Rational Farming Technology, a nature harnessed complete organic package of practice. This approach repurposes coir pith—traditionally a waste product that contributes to soil and water pollution as well as methane emissions—by subjecting it to Novcom Composting Technology, a process that bio-converts the residue into a safe, stable, and mature compost within 30 days; the resulting product is enriched with native microflora essential for rapid soil microbial regeneration. The Novcom coir pith compost was applied at 40 ton/ha to rehabilitate soils deemed unsuitable for vegetable and other agricultural crops. Post-transplanting, Inhana Plant Health Management solutions were periodically administered according to the recommended schedule, effectively promoting balanced crop growth, enhancing plant immunity, and fortifying defense mechanisms against pests and diseases, thereby reducing pesticide dependency; any minor pest issues that arose were controlled using on-farm neem-based concoctions. Furthermore, the formulation of the Clean Food Net Zero (CFNZ) program was guided by five key criteria: (i) alignment with ecosystem services; (ii) governance by a sustainable agro-technology framework that equally emphasizes soil and plant health management to achieve the program's objectives; (iii) economic viability;

(iv) ease of adoption and social acceptability; and (v) replicability across large landscapes, irrespective of agro-ecological variability and crop choice.

Program undertaken at Mandya, India : Coconut Based Integrated Crop Cultivation towards development of Regenerative Agri-Net Zero Model

Under the IBM-IORF Sustainability Project, an innovative program was undertaken at Mandya to develop coconut-based Regenerative Agri-Net Zero Model by integrating scientific interventions and regenerative farming practices. Three distinct intercrop models were implemented within coconut plantations on marginal red gravelly soils characterized by low fertility and diminished microbial activity—soils traditionally considered unsuitable for nutrient-sensitive, short-duration vegetable crops. Through the elimination of chemical pesticides and nitrogen fertilizers, these lands were transformed into productive fields, thereby illustrating a sustainable, chemical-free approach to modern agriculture. The program was initiated with a comprehensive field and socio-economic survey, followed by grid-wise soil sampling and soil resource mapping, followed by demonstrations of Novcom coir pith composting to valorize coir waste into nutrient-rich compost. Farmers were engaged through meetings designed to develop awareness and impart technical know-how regarding regenerative farming principles, leading to the adoption of Inhana Rational Farming (IRF) Technology. Additionally, a plant health management regime was introduced under the Inhana Plant Health Management (IPHM) program, complemented by integrated pest management strategies utilizing alternate and on-farm concoctions. The circular economy models were rigorously analyzed for their impacts on crop yield, nutrient utilization, soil health, energy consumption, greenhouse gas emissions, and overall cost–benefit ratios—parameters deemed critical for improving the livelihoods of resource-poor farmers. By emphasizing resource efficiency, waste minimization, and the systematic recycling, reusing, and regeneration of resources, this program not only optimized productivity but also reduced environmental impacts, thereby enhancing both the economic prospects and well-being of the farming communities involved.

Inhana Rational Farming Technology

Inhana Rational Farming (IRF) Technology, developed by Dr. Phalguni Das Biswas: pioneer in nature harnessed organic farming technology in India with over 25 years of research experience—provides a nature-receptive pathway for sustainable crop production by harmonizing the interrelated components of the ecosystem. This innovative approach enhances both ecological health and economic sustainability by focusing on two principal objectives: the energization of the soil system to promote its role as an effective growth medium and the energization of the plant system to facilitate optimal nutrient extraction, utilization, and assimilation, as well as to stimulate intrinsic biochemical and structural defenses (Bera et al., 2014). Central to IRF Technology is the use of specially formulated In-House solutions for soil and plant energization. These solutions incorporate technology-specific plants that store the energetic properties of the five basic elements—earth, water, fire, air, and space—as well as the five basic life forces, also known as Prana Shaktis. Selection of these plants is governed by parameters such as sunrise, sunset, seasonal changes, and other critical environmental factors. Their botanical extracts are subsequently potentized and energized following the Element Energy Activation (E.E.A.)® principle, a method that underscores the significance of “Chaitanya Shakti” or the basic life force, which is fundamentally manifested as solar energy.

According to the E.E.A. principle, all living organisms can be likened to complex machines driven by this life force, where two major processes operate continuously: self-nourishment and self-protection. Self-nourishment is supported by the Panchamahabhutas, with earth contributing to nutritional content and structure formation, water facilitating nutrient transport, fire driving metabolism and photosynthesis, air enabling respiration, and space providing the necessary environment for biochemical reactions and plant growth. In contrast, the self-protection mechanism is activated when any imbalance occurs in these vital functions; here, the Prana Shaktis—Apana (governing root function and nutrient extraction), Samana (regulating transpiration), Udana (influencing photosynthesis and enzyme secretion), Prana (controlling respiration), and Vyana (ensuring spatial adequacy for metabolic activities)—collectively work to restore equilibrium. By stimulating these internal life forces rather than relying on external chemical interventions, IRF Technology effectively overcomes plant diseases and pest infestations, ensuring balanced nutrient uptake and improved resilience. This integrative approach, based on precise “Energy Management,” tailors solutions to specific crop and agro-climatic conditions, thereby laying the groundwork for sustainable, chemical-free agriculture.

Coir Pith Composting with Novcom Composting Technology

Novcom Composting Technology harnesses the Element Energy Activation (EEA) Principle to create an optimal environment that accelerates microbial self-generation and expedites the biodegradation of coir pith, a byproduct of coconut processing, into high-quality organic compost. This method employs controlled aeration, precise temperature regulation, and effective moisture management to yield a consistent, microbe-rich product that not only improves soil fertility and water retention but also supports sustainable agriculture by reducing waste and

curtailing the reliance on chemical fertilizers. In a designated upland, flat area, the process begins with constructing a 10 ft. × 8 ft. × 6 ft. support structure made of bamboo strips and coconut leaves, designed to accommodate an approximate 8–9-ton heap of coir pith compost. The preparation involves applying a basal layer of cow dung slurry on the floor and inner walls of the support structure to establish an initial microbially active base. Coir pith is then mixed with cow dung slurry at an 80:20 weight ratio and layered in increments of approximately 0.5 ft. until the structure is filled, with each layer receiving about 60 ml of Novcom solution—this solution is prepared by diluting 25 ml in 5 liters of water—to facilitate microbial activation. Due to the inevitable compression of the material as it is layered, a total of 16 layers (amounting to about 2000 ml of Novcom solution) is required to reach the final 6-ft. height. After assembly, the compost heap is covered with coconut leaves and left undisturbed for the initial 9 days to promote in situ microbial activity. On the 10th day, one side of the heap is opened and the material is thoroughly mixed using a JCB, and the restructured heap is again treated with 2000 ml of the Novcom solution. This mixing process is repeated on the 20th day to ensure uniform microbial distribution and further acceleration of the composting process. Ultimately, by the 30th day, the composite material transforms into a matured, nutrient-rich compost that reflects the efficacy of the EEA Principle in converting a challenging organic residue into a sustainable agricultural resource, aligning with environmentally conscious waste management practices and the principles of circular economy in agriculture (Bera et al., 2023).

Compost, Soil, Crop Productivity, and Energetics Analysis

In this study, fifty composite samples from distinct Novcom coir pith compost heaps were systematically collected and analyzed for various quality parameters in accordance with the standard methodology described by Seal et al. (2012), with the subsequent calculation of a Compost Quality Index following the protocol of Bera et al. (2013). Soil quality was concurrently assessed by procuring samples from the 0–30 cm depth prior to the initiation of the experiment and again one year later; these samples were subjected to rigorous evaluations of physicochemical properties and fertility parameters based on established methods (Jackson, 1973). Additionally, microbial biomass carbon was quantified using the dichromate oxidation method (Vance et al., 1987), while soil respiration was determined through chemical titration of trapped CO_2, and soil FDAH was measured as per the standard procedures outlined by Haney et al. (2008). Crop productivity was assessed following recognized guidelines (Patrick, 1999) and later converted to coconut equivalent yield, ultimately facilitating the computation of total system productivity using methodologies described by Ghosh et al. (2021) and Naveen Kumar et al. (2017). The energy dynamics of the system were evaluated by calculating metrics such as energy use efficiency, energy productivity, specific energy, energy intensiveness, and net energy, all derived according to the standardized procedures reported by Banaeian et al. (2011). Finally, the overall environmental impact was quantified by determining the system's carbon footprint using ACFA (version 2.0), a carbon computing standard specifically developed for Indian agriculture by the Inhana Organization Research Foundation (IORF) in collaboration with ICAR-ATARI, Kolkata (Zone-V) and i-NoCarbon Limited (i-NC), UK, based on relevant IPCC guidelines and substantiated by empirical research (IORF, 2024). Together, these comprehensive analyses provide critical insights into the quality of the compost and soil, the efficiency of nutrient and energy use, and the sustainability of crop production systems, thereby supporting the development of best practices for sustainable agricultural management and reducing the environmental impact of farming operations.

Result and discussion

The result and discussion section comprehensively addresses a range of key issues. It begins with an evaluation of Novcom coir pith compost quality and progresses to assess crop performance, nutrient use efficiency, pesticide load, energy transition, farm income, and employment generation. In addition, it examines the impact of the Regenerative Agri-Net Zero Model on soil quality and quantifies greenhouse gas mitigation achieved through the CFNZ program across various crops. The analysis further encompasses the development of the Regenerative Agri-Net Zero Models, presents a multifaceted impact assessment of these models, and critically evaluates the economic viability of sustainable agricultural initiatives.

Analysis of Novcom Coir Pith Compost Quality

A comprehensive investigation into the efficacy of Novcom Composting Technology was conducted through batchwise 30th day samples of Novcom coir pith compost to evaluate its quality as per National and International Standards. Central to this assessment was the measurement of the carbon-to-nitrogen (C:N) ratio, which declined markedly from an initial approximate value of 100:1 in raw coir pith to less than 30:1 by day 30, signifying rapid organic matter degradation. Concomitant with this decline, total nitrogen content increased by approximately 98%, while lignin content experienced an estimated 60% reduction within the same period, confirming substantial biochemical transformation. Correspondingly, organic carbon content reduced from about 51.78% in the untreated material to approximately 27.50% in the mature compost, aligning with the typical range observed in stable compost (16–38%). These chemical transformations were correlated by very high microbial load, with bacterial, fungal, and actinomycete populations reaching the order of 10^{16} c.f.u. per gram of moist compost, which attests to

the very intense microbial activity essential for accelerated biodegradation. The breakdown of complex organic compounds through microbial enzymatic processes, under optimal conditions, underscores the efficiency of the technology. Additionally, phytotoxicity bioassay tests confirmed the absence of deleterious compounds in the final compost product and revealed that the amendment actively promotes seed germination and root growth, thereby enhancing its agronomic value. Collectively, these results not only demonstrate significant improvements in physicochemical and biological compost parameters but also illustrate the environmental benefits of the technology, positioning Novcom composting as a robust and sustainable strategy for managing coconut processing residues and enhancing soil fertility while mitigating greenhouse gas emissions.

Table 1 : Physicochemical, nutritional, biological quality parameters and lignin content of Novcom coir pith compost.

Test Parameters	Raw Coir pith	Novcom Coir pith Compost
Physicochemical & Nutritional Quality		
Moisture (%)	65.2 – 78.5	69-2 – 74.1
pH (H_2O)	5.30- 5.21	6.24 – 6.78
EC (dSm^{-1})	3.01 – 3.51	2.13 – 2.68
Organic Carbon (%)	49.6 - 52.4	25.1 – 29.7
Total N (%)	0.43 – 0.61	0.89 – 1.28
Total P_2O_5 (%)	0.06 – 0.17	0.15 – 0.21
Total K_2O (%)	1.31 – 1.78	2.69 – 3.78
C:N	94:1 – 108:1	25:1 – 30.4
Biological Quality		
Bacteria (c.f.u. per gm moist compost)	-	$(31 - 78) \times 10^{16}$
Fungi (c.f.u. per gm moist compost)	-	$(17 – 34) \times 10^{16}$
Actinomycetes (c.f.u. per gm moist compost)	-	$(7 – 16) \times 10^{16}$
Stability, Maturity & Phytotoxicity Parameters		
CO_2 Evolution Rate ($mgCO_2$–C/g OC/day)	-	1.13 – 1.89
Germination Index (Phytotoxicity Bioassay)	-	0.91 – 1.11
Lignin Degradation Study		
Total lignin %	39.8 - 43.7	21.2 – 24.7

Crop performance, Nutrient Use efficiency, Pesticide Load, Energy Transition, Farm Income, Employment generation under Regenerative Agri-Net Zero Model

Crop productivity of coconut based intercropping under Regenerative Agri-Net Zero Model adopted in Mandya, Karnataka was compared with conventional coconut based intercropping practice. Under IBM-IORF Sustainability project, 3 major coconut based intercropping viz (i) CBCE 1 : Coconut -Millet – Vegetable, (ii) CBCE 2: Coconut - Maize – Vegetable and CBCE 3: Coconut – Ginger was taken under study and comparative assessment was done under Conventional Farmers Practice (CFP) and Clean Food Net Zero (CFNZ) program.

Table 2 : Comparative study of crop performance, nutrient use efficiency, pesticide load, energy productivity, income generation under CFP and CFNZ management

Sl No	Parameters	Coconut-based Integrated Farming Systems					
		CBCE 1		CBCE 2		CBCE 3	
		CFP	CFNZ	CFP	CFNZ	CFP	CFNZ
1	Coconut Equivalent yield	9473	10666	11044	12574	23025	28535
2	System Productivity	14555	16387	16991	19345	35424	43900
3	Nutrient Use Efficiency	35.96	50.94	35.43	53.07	29.61	32.58
4	Nutrient Use Efficiency (based on availability in org. manure)	35.96	84.90	35.43	88.45	29.61	54.30
5	Pesticide Load	0.091	0.00	0.091	0.00	1.371	0.00
6	Crop Pesticide Pollution Index (CPPI)	0.006	0.00	0.006	0.00	0.084	0.00
7	Energy Productivity	0.28	0.94	0.29	0.99	0.24	0.69
8	Farm Income (gross)	562452	634150	568392	642784	328272	347656
9	Employment Generation Potential	125	245	131	251	230	350

Comparative analyses were conducted across three distinct coconut-based integrated crop production systems under two management regimes: Conventional Farmer Practice (CFP) and the Clean Food Net Zero (CFNZ) program. The results revealed that the CFNZ model consistently outperformed the CFP system, with average crop yield increases ranging from 12.6% to 23.9% across various cropping sequences. In addition, when total nutrient inputs (NPK) were provided through organic manure, nutrient use efficiency (NUE) was 33.8% higher under the CFNZ program. Notably, despite the inherent limitation that only about 30% of nitrogen, 60–70% of phosphorus, and 70% of potassium from organic manure are available to the first crop cycle, the overall nutrient uptake was significantly improved in the CFNZ system compared to CFP. This enhancement is largely attributable to the integrated Inhana Plant Health Management approach incorporated in the CFNZ program, which bolsters plant physiological functions, supports growth in low-input environments, and enhances resistance against both biotic and abiotic stresses. Furthermore, improvements in internal plant immunity and enhanced soil–plant–environment interactions were evidenced by a reduction in crop pesticide load, with the pesticide pollution index dropping to zero under CFNZ—a critical indicator for safe food production. Energy productivity also increased dramatically, exhibiting gains between 187% and 247%, which underscores the effectiveness of the nature-harnessed pathways employed in the CFNZ system. Economically, while overall farm income under CFNZ increased by about 10% relative to CFP, a shift to monoculture coconut cultivation has the potential to boost gross income by more than 50%.

Impact of Regenerative Agri-Net Zero Model on Soil Quality

A comparative assessment of soil health under Conventional Farming Practices (CFP) and the Clean Food Net Zero (CFNZ) management revealed significant differences in soil quality improvements. The CFNZ approach, emphasizing regenerative techniques, demonstrated notable enhancements in both physico-chemical and biological soil properties, surpassing the outcomes observed under CFP.

One of the most striking findings was a 25% increase in soil organic carbon (SOC) in CFNZ-managed fields post-intervention, while CFP fields exhibited negligible changes. This elevation in SOC is critical as it enhances soil structure, water retention, and nutrient availability, contributing to overall soil fertility. In terms of nutrient dynamics, both management systems showed improvements in available nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) levels. However, CFNZ fields demonstrated a more balanced nutrient profile, indicative of sustainable nutrient cycling facilitated by regenerative practices.

Table 3 : Comparative study of soil quality parameters

Soil Physico-chemical parameters	pH	EC (1:5) dSm^{-1}	Org. C%	Av NO_3 (ppm)	Av-N	Av P_2O_5	Av. K_2O	Av- SO_4
					< ---------- Kg/ha ---------->			
Before experimentation								
CFP	6.14	0.053	0.50	29.19	168.04	32.43	534.26	424.58
CFNZ	6.15	0.051	0.53	31.02	165.70	30.15	468.90	432.10
Post Experimentation								
CFP	6.15	0.054	0.51	32.10	213.10	32.10	542.10	356.10
CFNZ	6.23	0.059	0.66	28.80	203.25	38.97	505.05	395.54
Soil Biological parameters	Bacteria	Fungi	Actino-mycetes	MBC[1]	FDA[2]	SR[3]	qMBC[4]	qCO_2[5]
Before experimentation								
CFP	10 x 10^4	11x 10^3	4 x 10^3	46.70	14.46	0.16	0.93	3.43
CFNZ	12x 10^4	9 x 10^3	6 x 10^3	45.8	13.2	0.17	0.86	3.71
Post Experimentation								
CFP	16x 10^4	9 x 10^3	6 x 10^3	45.5	15.10	0.15	0.89	3.30
CFNZ	59x 10^5	13 x 10^4	19 x 10^3	66.8	19.01	0.21	1.01	3.14

Note : [1]MBC; Microbial biomass carbon (micro gm biomass C/gm dry soil/hr), [2]SR:Soil Respiration, [3]FDA : Soil Fluorescein diacetate hydrolysis activity (µg/gm dry soil), [4]qMBC :Microbial Quotient, [5]qCO_2: Metabolic Quotient

Biological indicators further underscored the efficacy of the CFNZ program. There was a substantial increase in microbial populations, including bacteria, fungi, and actinomycetes, in CFNZ implemented fields. This microbial proliferation is attributed to the application of high-quality Novcom compost at 40 tonnes per hectare, which

provides a rich substrate for microbial growth. Enhanced microbial activity was evidenced by increased microbial biomass carbon (MBC) and fluorescein diacetate (FDA) hydrolysis activity, both of which are indicative of a dynamic and healthy soil microbial community. These biological enhancements are vital for nutrient mineralization and overall soil ecosystem functioning.

The comparative analysis clearly indicates that the CFNZ program fosters a more robust and resilient soil environment compared to conventional practices. By improving both chemical and biological soil properties, the CFNZ program not only enhances immediate soil fertility but also contributes to long-term agricultural sustainability. These findings align with broader research indicating that regenerative agricultural practices can significantly improve soil health and productivity.

GHG Mitigation under CFNZ program in different crops

Agriculture occupies a pivotal role in both generating GHG emissions and offering pathways for their mitigation through carbon sequestration. The 25.2-hectare Clean Food Net Zero (CFNZ) program in Mandya, Karnataka, India towards development of Regenerative Agri-Net Zero Model, which employs IRF Technology, exemplifies this dual potential. Through substantial carbon sequestration, notable emissions reductions, and the enhancement of ecosystem health, the CFNZ program illustrates how innovative agricultural practices can lead to net-zero emissions without compromising productivity.

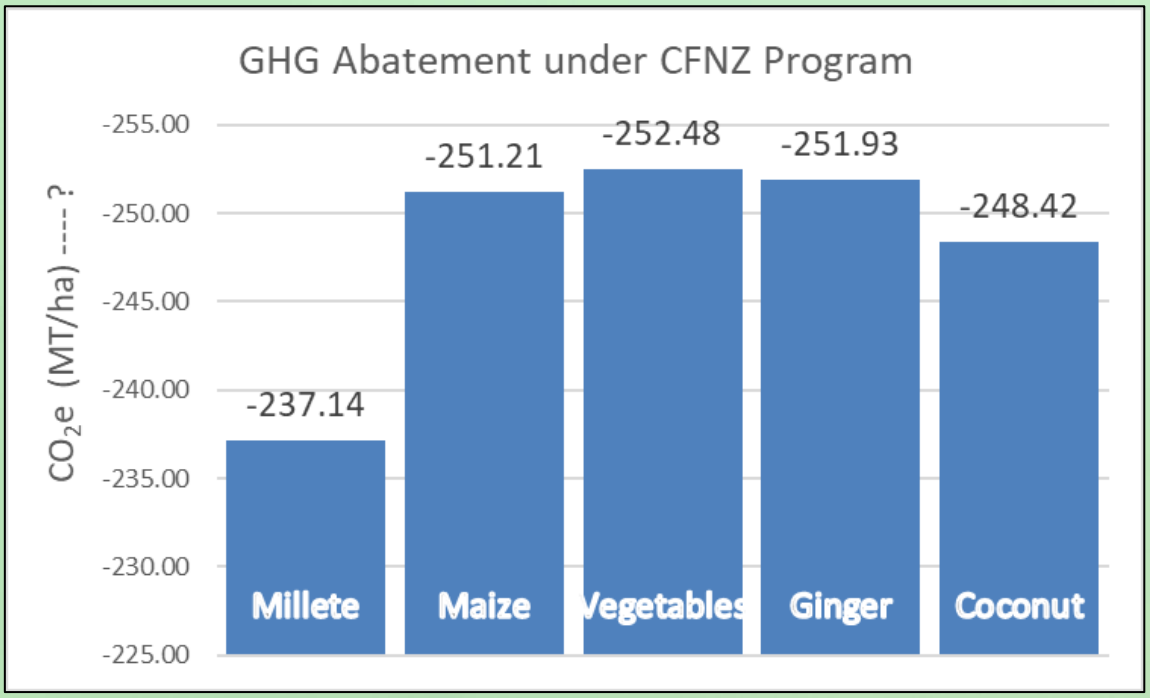


Fig 1 : GHG abatement potential under CFNZ program.

A GHG evaluation conducted using the ACFA (Version 2.0) tool demonstrated that replacing conventional farming practices (CFP) with the CFNZ program yields significant abatement of CO_2e per hectare across multiple crops. For instance, while CFP results for millet, maize, vegetables, ginger, and coconut registered at 1.14, 1.39, 2.65, 2.30, and –1.66 ton CO_2e/ha respectively, the corresponding CFNZ values dropped dramatically to –236.01, –249.83, –249.83, –249.63, and –250.08 ton CO_2e/ha. This translates to GHG abatement potentials of –237.14, –251.21, –252.48, –251.93, and –248.42 ton CO_2e/ha, respectively, thereby underscoring the significant environmental benefits of the CFNZ approach in fostering sustainable and climate-resilient agriculture.

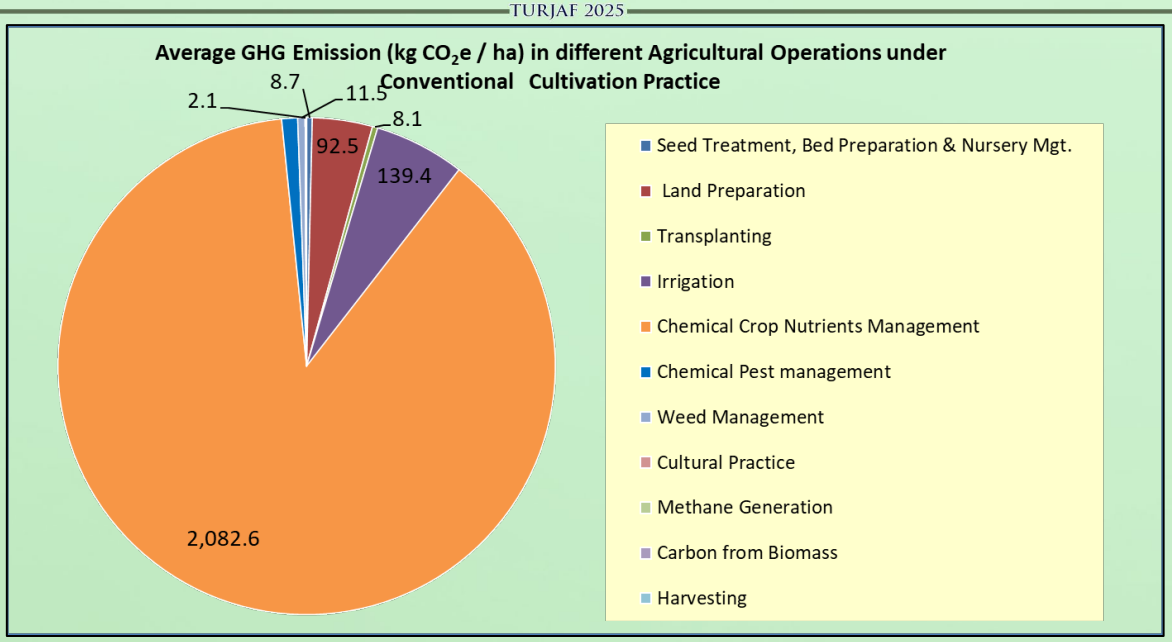


Fig 2 : Average GHG emission ($KgCO_2e$ /ha) of different agricultural operations under CFP at Mandya, India studied under IBM-IORF Sustainability Program

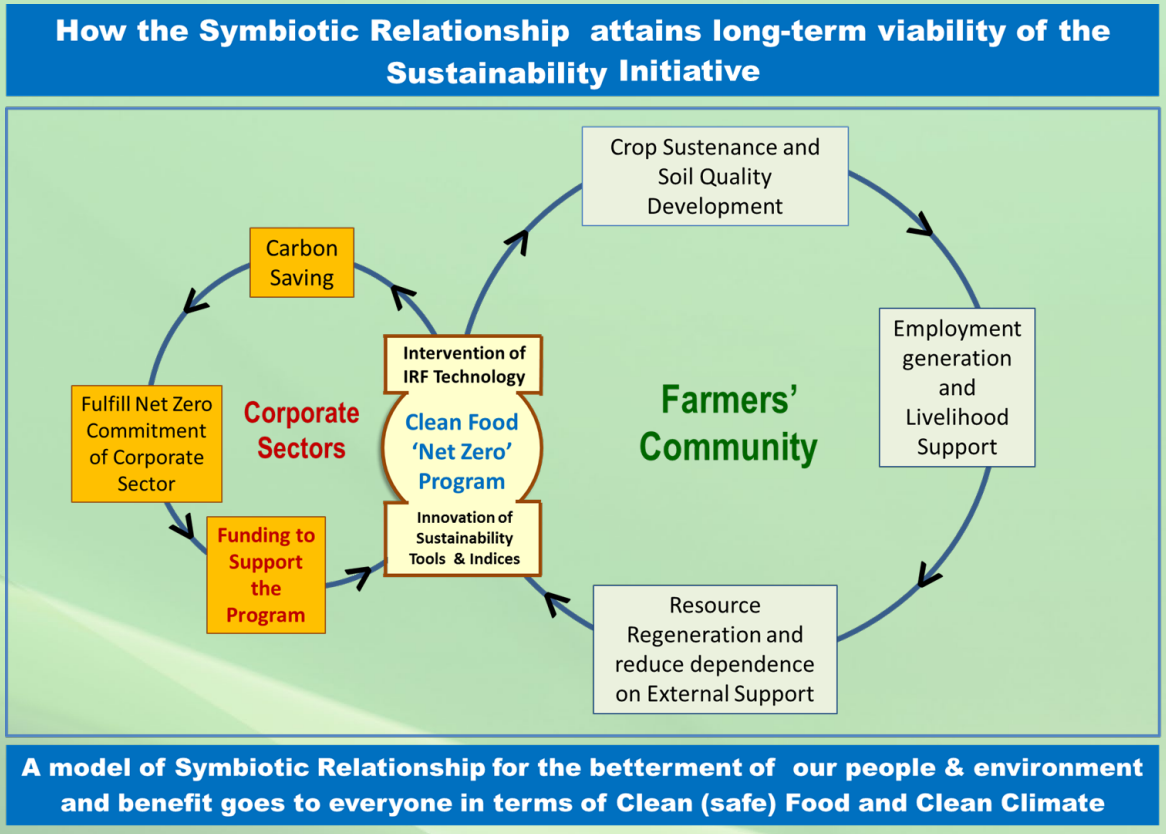


Fig 3 : The Regenerative Agri-Net Zero Model showed a symbiotic relationship between corporate net zero goal and farmers sustainability

Development of the Regenerative Agri-Net Zero Models

The Regenerative Agri-Net Zero Model represents an innovative framework that decouples economic growth from resource depletion and environmental degradation by closing the carbon cycle and promoting waste to compost development movement. This approach integrates waste recycling, resource efficiency, and renewable energy to conserve natural resources while actively mitigating greenhouse gas emissions, and it has been successfully implemented under the IBM-IORF Sustainability Project in Mandya, Karnataka—the first agro-net zero model in India certified by i-NoCarbon, UK. By combining Inhana Rational Farming (IRF) Technology with Novcom

Composting Technology, the project has transformed approximately 2000 tonnes of coir pith, a byproduct of coconut processing, into a high-quality compost applied at 40 tonnes per hectare over a 25.2-hectare area for two consecutive years. The rapid bioconversion process—completing within just 30 days—yields compost that is exceptionally rich in native microflora, which catalyzes soil microbial regeneration and effective carbon sequestration. Beyond enhancing soil health, this model sustains crop productivity, aligns with economic services, and facilitates the production of pesticide-free food, thereby securing sustainable livelihoods.

Moreover, it exhibits a very high carbon mitigation potential; GHG evaluations using the ACFA (Version 2.0) tool reveal that the model can mitigate approximately 250.39 metric tonnes CO_2 equivalent per hectare, in addition to the bioconversion process mitigating around 6000 tonnes CO_2 equivalent per 1000 tonnes of waste and further abating nearly 6300 tonnes CO_2 equivalent by eliminating synthetic nitrate fertilizers. This robust carbon abatement program not only support corporate net-zero and sustainability initiatives but also ensure that the program has no spillover effects or scope for greenwashing. In fact, the model's significant social and environmental footprint establishes it as one of the best decarbonization programs currently available, setting a scalable benchmark for sustainable, climate-resilient agriculture and advancing global sustainable development goals.

Multifaceted Impact Assessment of Regenerative Agri-Net Zero Model : Enhancing Sustainable Agriculture, Environmental Regeneration, and Livelihoods of Small and Marginal Farmers

The Clean Food Net Zero (CFNZ) program represents a transformative advancement in sustainable agriculture by integrating organic soil management, rapid waste bioconversion, and advanced plant health practices to deliver significant environmental, agronomic, and social benefits. Environmentally, the model achieves considerable greenhouse gas mitigation—up to 250 tons CO_2 equivalent/ha—while enhancing soil carbon sequestration by approximately 300 kg/ha/year through the conversion of diverse organic wastes into nutrient-rich compost in just 21 days. This rapid bioconversion process revitalizes degraded lands by boosting soil microflora and earthworm activity and supports pesticide residue–free food production in compliance with FAO-WHO-Codex standards, ultimately reducing chemical input burdens and promoting ecological sustenance across 100 hectares serving over 20,000 consumers. Agronomically, the CFNZ program drives a 15–25% increase in crop productivity relative to conventional practices, simultaneously achieving up to 32% lower energy input and over 60% higher energy productivity, which is further reinforced by the development of climate-resilient organic seeds that enhance farmers' adaptability to climate change. Socially, the model serves as a critical catalyst for the economic upliftment of small and marginal farmers by transferring sustainable crop technologies and comprehensive knowledge support, thereby fostering greater food security and income generation. Furthermore, by bridging the gap between grassroots farming and corporate sustainability efforts, the CFNZ program enables the integration of sustainable agricultural practices into supply chains, aligning corporate initiatives with broader net-zero objectives and Sustainable Development Goals. In summary, this integrated approach not only regenerates environmental health and boosts agricultural productivity but also delivers profound socio-economic benefits, establishing a scalable, win–win framework for sustainable development.

Economic viability of Agricultural Sustainable initiatives: A detailed insight and impact of carbon funding

An analysis of cultivation costs and income indicates that adopting any sustainable project involves extra expenses that erode profitability. Our experience shows that when sustainable practices fail to sustain crop yields or lack technological enhancements to improve system efficiency, the gap in the return on investment (ROI) widens further. Consequently, the cost and return aspects of sustainable projects are seldom discussed within the framework of hard economics, with the discussion taking a holistic view and typically focused on broader environmental benefits—such as enhanced soil health and ecological sustenance—rather than on direct financial outcomes.

Introduction of Inhana Rational Farming (IRF) technology reduces operational costs by sustaining crop productivity and lowering expenses associated with pest and disease management. However, the organic inputs required for sustainable soil management remain significantly more expensive than chemical fertilizers. The adoption of Novcom composting technology further cuts management time, enhances compost quality, and improves the efficacy of soil application. It is evident that conventional sustainable initiatives without technological intervention demand a premium of 80–100% to achieve net benefits comparable to conventional farming practices. In contrast, the introduction of IRF technology effectively narrows the return on investment gap, requiring only a 30–35% premium—particularly when following the Agri-Net Zero model with its intense carbon mitigation objectives. On the other hand, carbon funding under the Agri-Net Zero model can potentially boost net profits by more than 200%.

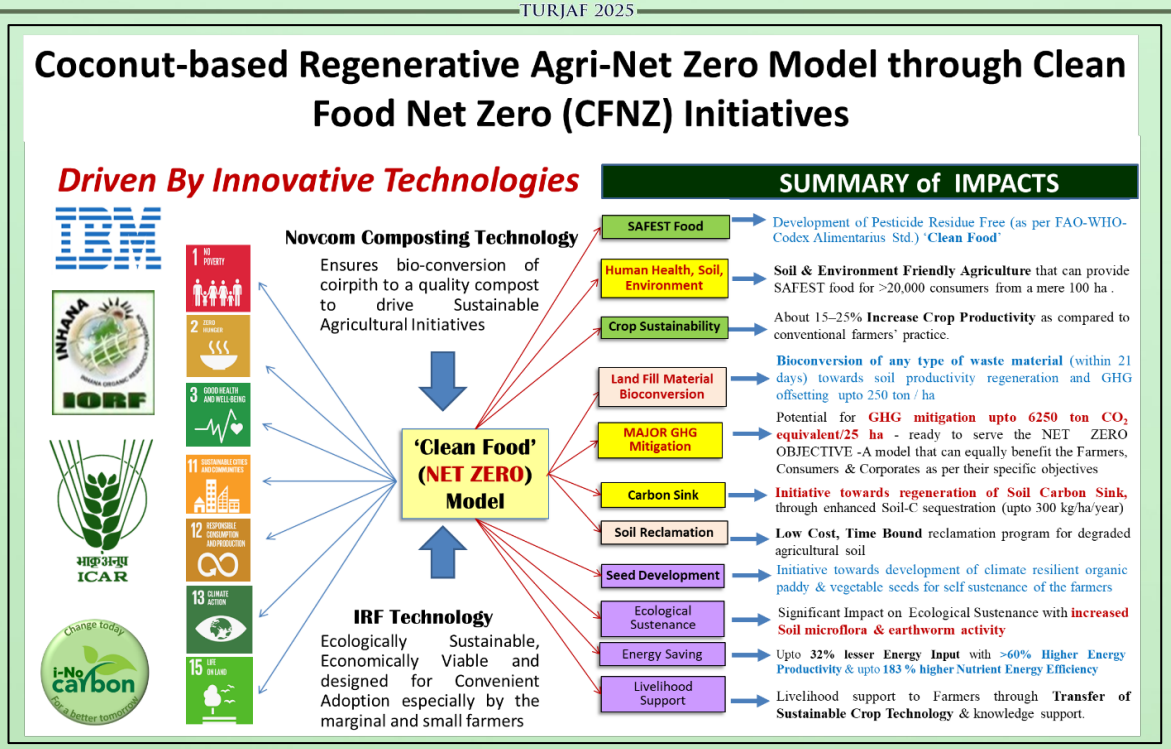


Fig 4 : The Regenerative Agri-Net Zero model driven by Clean Food Net Zero (CFNZ) program through the adoption of Inhana Rational Farming Technology exhibited a multifaceted social and environmental footprint.

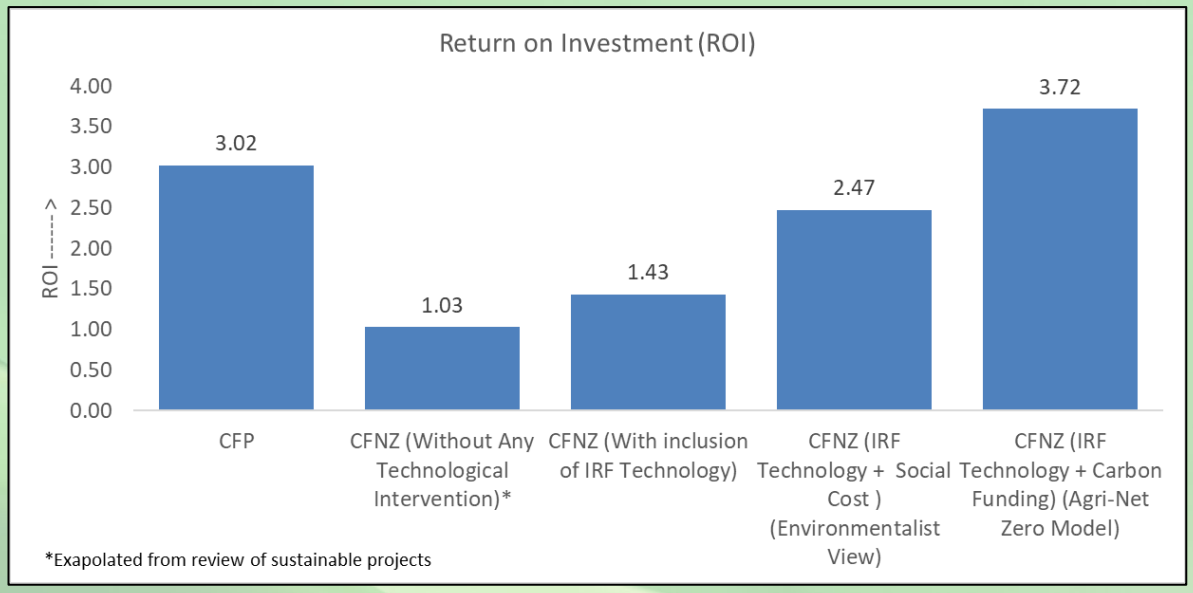


Fig 5 : Return on Investment (ROI) in sustainable initiative – a detailed Insite.

One of the most intriguing outcomes is the return on investment (ROI) in sustainable agriculture. Despite improvements in yield, reductions in pest and disease incidence, and enhanced energy productivity, the ROI for these initiatives remains lower than that of conventional farming—primarily due to the increased costs of sustainable soil management compared to chemical fertilizers. The Agri-Net Zero Model, integrated with climate-resilient regenerative agriculture, offers a promising solution by linking corporate sustainability commitments through CSR, ESG, and dedicated funding with farmers' practices via carbon mitigation objectives. Economic analyses indicate that when generated carbon credits are repurchased at a moderate price (around $60 per metric ton, even when international prices exceed $100), the Agri-Net Zero Model becomes significantly more viable, bolstering overall profitability. While environmental benefits such as improved soil health and long-term climate

change mitigation are critical and widely discussed among policymakers, agronomists, and environmentalists, the hard economic metrics of cost and return receive far less attention. For resource-poor farmers, who prioritize immediate operational sustainability over uncertain future gains, expecting them to shoulder these costs is impractical; instead, the lion's share of responsibility must be borne by policy makers, government bodies, and corporate institutions. Sustained support over a three-to-five-year period can further rejuvenate farming systems by gradually reducing soil management costs, enhancing productivity, and enabling fair market price realization, thereby driving the long-term viability of sustainable agricultural practices.

Conclusion

The study decisively establishes the Regenerative Agri–Net Zero Model as a scalable, economically viable, and scientifically robust framework for climate-resilient agriculture. By integrating advanced organic soil and plant health technologies—specifically Inhana Rational Farming and Novcom Composting—within a regenerative, circular bioeconomy, the model delivers transformative outcomes. It substantially enhances crop yields, nutrient use efficiency, and farmer incomes while restoring soil health through increased organic carbon sequestration and revitalization of microbial ecosystems. It achieves significant greenhouse gas mitigation, supports pesticide-residue–free food production, and reduces reliance on synthetic fertilizers—ensuring sustained ecological balance. Critically, the model bridges corporate sustainability goals with the resilience of small and marginal farmers, producing tangible co-benefits such as improved energy productivity, enhanced ecosystem adaptability, and access to carbon financing. Third-party certification affirms its environmental integrity, confirming the absence of greenwashing or negative spillover effects. To accelerate its impact, a clear policy directive is needed to promote nationwide adoption of the Regenerative Agri–Net Zero Model through targeted incentives, carbon credit integration, and its inclusion in corporate ESG frameworks—aligning agricultural sustainability with national climate goals. Altogether, the model sets a transformative benchmark, aligning with global Sustainable Development Goals and offering a future-ready blueprint for corporate ESG ambitions and rural livelihood sustainability.

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ID: 701

Sustainability and Environmental Footprints of AI-Integrated Agrifood Production Systems

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Abstract

Global food systems are facing challenges in meeting the rising demand for food while also reducing their environmental impact, including carbon and water footprints. Artificial intelligence (AI) offers promising solutions to improve efficiency, effectiveness, and resilience throughout the food supply chain. However, the use of AI in food production, particularly in advanced industrial settings such as Industry 4.0 and 5.0, also presents its own environmental and social challenges. This study examines the potential benefits of AI in creating a sustainable food system, including better resource use, less waste, improved water efficiency, and enhanced crop protection. It also considers the significant energy needed to train and operate AI systems. To ensure AI-based technologies truly support sustainability in food production, we need a balanced approach that includes fair access, responsible resource management, and integrating AI with other sustainable agricultural practices. Future efforts should focus on making AI tools easier to use for a wider audience, implementing strong governance rules, and aligning AI advancements with environmental, economic, and social impacts. By preventing these challenges, AI can be used to develop a more efficient, resilient, and environmentally friendly food resource system, contributing to global sustainability goals.

Keywords: *Sustainability, environmental footprints, carbon and water footprints, AI-integrated food production, zero waste and water efficiency*

ID: 704

Effects of Allantoin, A Stress-related Purine Metabolite, on Salt Stress Mitigation in Maize (*Zea mays L.*) During Early Germination Stage

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Abstract

Soil salinity is a major constraint on global agricultural productivity, particularly affecting salt-sensitive crops like maize (*Zea mays L.*). This study investigated the potential of allantoin, a purine metabolite, to mitigate salt stress during maize seed germination and early seedling development. Maize seeds were pretreated with varying concentrations of allantoin (0, 0.5, and 1 mM) and subsequently subjected to 150 mM NaCl stress under controlled conditions. Morphological parameters, including shoot and root length, fresh and dry weight, germination percentage, and vigor index, were assessed. Biochemical analyses quantified oxidative stress markers (malondialdehyde, hydrogen peroxide), photosynthetic pigments, protein content, osmolyte accumulation, and antioxidant enzyme activities. Salt stress significantly inhibited germination and seedling growth, increased oxidative stress, and disrupted biochemical homeostasis. However, allantoin pretreatment, particularly at 0.5 mM, effectively alleviated these adverse effects. Allantoin-treated seedlings exhibited improved germination, enhanced growth, reduced oxidative damage, and modulated biochemical responses. This research demonstrates that allantoin can enhance salt tolerance in maize during germination. These findings suggest that allantoin pretreatment represents a promising strategy for improving maize establishment and productivity in saline environments.

Key Words: *Maize, Salt stress, Allantoin, Germination, Oxidative stress*

ID: 705

Bangladeshi Medicinal Plants with Anthelmintic Potential: A Scoping Review

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Abstract

Helminth infections, particularly those caused by soil-transmitted helminths (STHs), pose a substantial global health threat, affecting over 1.5 billion individuals, particularly in tropical and subtropical regions. These infections are common in impoverished communities, particularly in rural areas and urban slums of Bangladesh, which lack adequate sanitation systems. These infections impose a significant economic burden on developing countries by reducing livestock productivity and deteriorating animal health. The rise of anthelmintic resistance to conventional anthelmintics, particularly in livestock, and the potential for its spread to humans underscore the urgent need for alternative therapies. This review aims to explore the potential of medicinal plants in Bangladesh as alternative anthelmintic treatments by examining studies conducted over the past two decades, focusing on species native to the country. A comprehensive literature search was conducted across various databases, including PubMed and search engines like Google Scholar, to identify only full-length, English-language articles. The review identified fifty-six medicinal plants belonging to thirty-six different families, with Fabaceae (seven species),being the most diverse followed by Lamiaceae (four species), and Apocynaceae, Combretaceae, and Cucurbitaceae (three species each). The conservation status assessment revealed 29 plants classified as Least Concern (LC), 24 as Not Evaluated (NE), and 3 as Data Deficient (DD). A thorough literature review resulted in the development of a detailed table summarizing diverse anthelmintic evaluations. This table provides data on extract types, with aqueous and alcoholic extracts being the most prevalent, and testing methods, which include both in vitro and in vivo assays against parasitic and non-parasitic nematodes. Furthermore, it addresses assessment parameters such as egg hatch inhibition, larval migration inhibition, and paralysis induction. The review highlights the growing importance of Bangladeshi medicinal plants as alternative medications in the face of rising anthelmintic resistance. Further studies should focus on the extracts, fractions, and compounds derived from these plants, evaluating their efficacy as anthelmintic agents for use in livestock, companion animals, and humans. As traditional anthelmintics become ineffective due to resistance, medicinal plants offer a promising alternative, highlighting the need to explore their potential in humans, animals, and livestock.

ID: 706

Chemical and nutritional assessments of *Balanite aegyptiaca* seed cake used as additives in diets for *Clarias gariepinus* post juveniles (catfish).

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Abstract

The chemical analysis and nutritional assessment of *Balanite aegyptiaca* seed cake (BASC) were investigated to evaluate the effect of using BASC as additive at 0 %, 10 %, 20 % and 30 % inclusion levels in catfish diets and performance. Two hundred and twenty-five *Clarias gariepinus* post juveniles (catfish) with initial weight ranging from 28.06±0.35g to 31.92±0.97g were divided into five experimental groups. Each group with three replicate of fifteen fishes stocked in 40-litre plastic bowls were fed twice a day at 3 % of their body weight with five formulated diets for 56 days. Diets 1 and 2 (standard feed and 0 % BASC) were used are control while diets 3, 4 and 5 containing respectively 10 %, 20 % and 30 % of BASC were the experimental diets. The protein content in the prepared feed increased gradually within the groups due to the high protein content (51.31±0.13%) of BASC. All the fish increased significantly ($P \leq 0.05$) in weight, length, nitrogen metabolism, condition factor, survival rate and in other growth parameters above the initial values with the highest percentage in 30% group. Haematological analysis showed a slight increments in the blood parameters (PCV, Hb, RBC WBC and MCHC) except for MCH, MCV and platelets ($p<0.05$). No significant differences were observed in ATP, AST, ALT, globulins and albumin in fish fed on BASC containing diets. Histology showed a mild congestion of the blood vessels in the Kidney of the control and 10 %, a moderate portal congestion and diffuse vacuolar degeneration in the liver of the control and 20%. No significant differences were observed in all gills, heart as well as in the kidney and liver of other experimental fishes. *B. aegyptiaca* seed cake could be a nutritional source without any toxic effect to *Clarias gariepinus* post juveniles (catfish).

Key Words: *B. aegyptiaca* cake, *C. gariepinus* post juveniles, growth performance, nutritional source

ID: 707

Evaluation of antibacterial efficacy of albedo of *Citrus medica* fruit against pathogenic microorganisms

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Abstract

The present study aimed to explore the antibacterial effect of the albedo of *Citrus medica* fruit. For this pursuit, extracts were prepared in methanol, ethyl acetate, n-hexane, cold water, and hot water. These extracts were then tested against both plant and human pathogenic bacterial species. The disc diffusion method measured the antibacterial activity of extracts from the albedo of fruit at different concentrations (1000µg/disc, 2000µg /disc, and 3000 µg /disc). The findings of the study showed that hot water and ethyl acetate extract formed the same zone of inhibition against *Escherichia coli* (*E. coli 0157:H7) and Citrobacter freundii* (53% ZI) at 3000 µg/disc. Similarly, ethyl acetate extract was active against *Agrobacterium tumefecien* and produced a 53% zone of inhibition at 3000µg/disc. Methanol and cold water extract at 3000µg /disc formed a 41% zone of inhibition against *Agrobacterium tumefecien* and *Xanthomonas oryzae*.

Ethyl acetate extract n-hexane was active against *Bacillus atrophaeus* and *Salmonella typhi* by producing 41% zone of inhibition. The ethyl acetate extract showed antibacterial potential against *P. aeroginosa* and formed a 41% inhibition zone at 3000µg/disc. Furthermore, the growth of *Rhizobacteria solani* was inhibited equally by methanol and n-hexane extract (33%ZI) at 3000µg /disc. Hot water extract produced a 41% zone of inhibition against *C. freundii* . However, ethyl acetate and n-hexane extracts formed 28 and 23% zones of inhibition against *Rhizobacter* and *C. freundii* respectively.

Keywords: *Medicinal plants, Extracts, Antimicrobial potential, Zone of inhibition*

ID: 708

Unveiling the role of spirulina in the mitigation of sumithion-induced toxicity in Thai pangas, *Pangasianodon hypophthalmus*

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Abstract

Sumithion is an organophosphate insecticide, widely used in aquaculture ponds to eradicate aquatic insect (mainly tiger bugs), typically applied before stocking fish larvae. However, it adversely affects non-target aquatic organisms, particularly fish. This study was conducted to evaluate the potential toxicity of sumithion in Thai pangas (*Pangasianodon hypophthalmus*) as well as the role of dietary *Spirulina platensis* in mitigating the toxic effects of sumithion. Over a 42-day trial, a total 240 of striped catfish fingerlings were exposed to four different treatments: control (without Sumithion or Spirulina), sumithion (0.6 mg/L), Spirulina (50 g/kg feed) and combined treatment (sumithion + Spirulina) with three replicates each. Sumithion-treated fish exhibited altered hemato-biochemical indices (hemoglobin and glucose) as well as erythrocyte morphology such as cellular (teardrop, twin, fusion) and nuclear (nuclear bridge, nuclear buds, notch, karyopyknosis) abnormalities. Furthermore, the sumithion-treated fish exhibited a considerable difference in the expression levels of antioxidant genes with down-regulated of *SOD*, *CAT* and up-regulated of *GPx* as well as immune-related genes with up-regulated of *MHC-II* and *IFN-β2* and down-regulated of *IL-1β* and *IFN-α2* compared to control. Moreover, it has been found that Spirulina along with sumithion improves the immunological, anti-oxidative, and physiological conditions of fish. The present study unveiled the implementation of dietary Spirulina to be an effective approach to mitigate sumithion-induced stress and optimize health condition in striped catfish by improving haemato-biochemical index and immune-antioxidant genes expression.

Keywords: *aquaculture, spirulina, sumithion, antioxidant genes, immune modulation*

ID: 709

Feeding and reproduction of *Aphelenchus avenae, Aphelenchoides sacchari* and *Aphelenchoides clarus* on cultures of soil related fungi *Aspergillus niger, A. flavus,* and *Fusarium oxysporum*

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Abstract

Aphelenchus avenae Bastian 1865,and *Aphelenchoides clarus* Thorne and Malek, 1968, and *Aphelenchoides sacchari* Hooper 1958 are mycophagous nematodes belonging to the *Aphelenchida* order. These nematodes are highly distributed in vineyards in Turkey. In this study, the reproduction potential of these three nematodes was determined under in-vitro conditions using the fungi *Aspergillus niger, A. flavus,* and *Fusarium oxysporum.* The fungi used in the experiments were isolated from soils collected from vineyards and maintained on Potato Dextrose Agar (PDA) at 25°C. Nematodes were extracted from the soils using the modified Baermann funnel method. After one week of fungal growth, 30 females of each nematode species (*A. avenae, A. clarus* and *A. sacchari*) were hand-picked and inoculated into the fungal cultures, which were then incubated for about a month at 25°C. At the end of the month, all nematode species reproduced in the Fusarium oxysporum culture. The reproduction rate was the lowest in *A. avenae* (44 individuals, a 1.46-fold increase) and the highest *A. sacchari* (177 individuals, a 5.9-fold increase). However, none of the nematodes reproduced in the *A. niger* or *A. flavus* cultures. The juvenile populations of *A. sacchari,* and *A.clarus* were abundant in the fungal cultures, and in petri dishes where the nematode population increased significantly, fungal cultures showed visible deterioration and a decrease in biomass.

Keywords: *Fungivore nematodes, fungal culture, nematode reproduction, fungi control*

ID: 710

A comparison of different selection indexes for milk traits in Friesian cows by using different relative economic values.

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Abstract

The data set contained 2181 normal lactation records of Friesian cows kept at Sakha Experimental Farm, Kafer El- Sheikh Government, belonging to Animal Production Research Institute, Ministry of Agriculture, Dokki, Cairo, Egypt were used to construct several selection indexes by using two relative economic values, actual relative economic value (REV_1) and one phenotypic standard deviation (REV_2). Variables studied were 305 day milk yield (305 d MY), 305 day fat yield (305 d FY) and 305 day Protein yield (305 d PY). Data were analysis by using MTDFREMAL Software. The model include the main effects of month and year of calving, parity and days open as covariate and random effects of animals, permanent environmental and errors.

The estimated means and standard deviations for 305 d MY, 305 d FY and 305 d PY were 2806 ±949 kg , 102 ±37 kg and 79 ±28 kg, respectively; and their estimated heritabilities 0.29±0.01, 0.24±0.02 and 0.29±0.02, respectively. Repeatability estimates were 0.37±0.05, 0.44±0.06 and 0.51±0.06 for 305 d MY, 305 d FY and 305 d PY, respectively. Phenotypic, genetic environmental correlations among different variables were positive and significant. Comparison of the two methods for estimating relative economic values explained no changes in any of the two methods for the expected genetic gain per generation for each variable. Our results indicate that, the two methods were succeeded in predicting the genetic progress per generation for the three variables studied. However, the second method (one phenotypic standard deviation) was recommended based on ease of estimation.

Key words: Selection indexes, milk, composition , Friesian cows

1. Introduction

Selection index is the best method of selection for several variables in livestock. It takes heritability of each variable, phenotypic variance of each variable, genetic and phenotypic correlations among variables and relative economic value of each variable **(Hazel and Lush, 1942).**

Relative economic values can estimate by different methods, actual economic value or net profit (**Khattab and Sultan, 1991; Atil et al, 2005; El- Awady, 2009 ; Kassab et al. 2024**), one phenotypic standard deviation **(Falconer and Mackay, 1996; Abosaq et al. 2017; Khattab et al. 2023; Kassab et al. 2024),** Lamont method (**Lamont, 1991; Abosaq et al., 2017 ; Khattab et al. 2023)** and one genetic standard deviation (**El- Awady, 2009** ;**Kassab et al. 2024).**

The main objectives of current study were to estimate phenotypic and genetic parameters for 305 day milk yield (305 d MY), 305 day fat yield (305 d FY) and 305 day protein yield (305 d PY) and constructed selection indexes by using two methods of relative economic values for Friesian cows.

2. Material and methods

Data were collected from Sakha experimental farm, belonging to the Animal Production Research Institute, Ministry of Agriculture, Dokki, Cairo, Egypt and comprising 2181 cows which completed one or more lactations. Animals were fed on Egyptian clover (*Trifolium alexandrinum*) during winter and spring season and during summer and autumn they were fed on concentrate ration and clover hay. Artificial insemination (AI) was used at random. Heifers were first inseminated at 18 months of age. In subsequent lactations, cows were initially inseminated 60 -70 days postpartum. Milking was performed twice daily at 7am and 4pm during the lactation period. Milk yield were recorded daily and milk components were analyzed weekly by using system of Milko–Scan 130 series, type 10900. Maintained at (ILMTC) related to Animal Production Research Institute (APRI), this have special program to estimate milk composition (fat and protein). Variables studied are milk, fat and protein yield in 10 months (305 d MY, 305 d FY and 305 d PY), respectively. Days open was computed as the interval between parturition and the date of successful mating.

Statistical Analysis:

Data were analysis by using MTDFREML Software Boldman et al. (1995), the statistical models included the fixed effects of month and year of calving and parity and days open as a covariate, and random effects of animal, permanent environmental effect and residual. Heritability (h^2) was estimated by using the following equation ($h^2 = \sigma^2a / \sigma^2a + \sigma^2pe + \sigma^2e$). Repeatability (t) was estimated by using the following equation ($t= \sigma^2a + \sigma^2pe/ \sigma^2a + \sigma^2pe + \sigma^2e$), where, σ^2a = additive genetic variance, σ^2pe= permanent environmental variance and σ^2e= random residual effects.

Selection Index Methodology:
Requires selection on an index or criterion (which correlates best with H):
$I = \sum_{i=1}^{n} (bi\ pi)$
I is selection index, b_i is a selection index weighing factor, p_i is a phenotypic measure and n is number of traits. The optimum set of selection index coefficients are those which maximize the correlation (r_{IH}) or minimize the squared deviation between the selection index and the aggregate genotype. The genetic and phenotypic parameters used for the calculation of the optimal index weights in all index calculations were those observed in the present study, Hazel (1943) proved that maximum r_{HI} is achieved when $Pb = Gv$, then The vector of optimal index weights (b) was calculated for each of the objectives as
$b = P^{-1}Ga$
where:
P^{-1} is the inverse of the phenotypic (co)variance matrix of the traits in the selection index, G is the genetic covariance matrix between traits in the selection goal and the selection index, and a is the vector containing the economic values for the goal traits.
Furthermore, the other different properties of the selection index were calculated as following:
Standard deviation of the index (σ_I) = $\sqrt{b'Pb}$,
Standard deviation of the aggregate genotype (σ_H) = $\sqrt{a'Ga}$
Correlation between the index and the aggregate genotype (accuracy)
$R_{IH} = \sigma_I / \sigma_H$

The genetic change per trait from selection ΔG (R_j) was calculated as:

$$\mathbf{R_j} = \frac{\mathbf{i^*b'^*G_j}}{\sigma_{\mathbf{i}}}$$

Where R_j = a vector with the genetic change per trait j, i is selection intensity (in the present study this was assumed to equal one), b′ is transpose of the vector containing the index weights, G_j is the j^{th} column of a G matrix containing the genetic covariance between the trait j and the index traits; and σ_i is the standard deviation of the index used. The expected response from selection using the objectives is illustrated in the present study as genetic gain following one cycle of selection with a standardized selection intensity of one.

Estimate of relative economic value (REV):
The economic values were calculated by two methods:
Actual relative economic value: The economic value for each variable was calculates based on the final actual net profit (Khattab and Sultan, 1991; Atil et al., 2005 ; Kassab et al. 2024).
One phenotypic standard deviation: Depending on the phenotypic standard deviation where $V_i = 1 / \sigma_p$. According to (Falconer and Mackay, 1996; Atil et al., 2005; Kassab et al., 2024). The weighted economic values according to the two methods of economic values are shown in Table 1.

Table 1. Relative economic values (REV) for different variables according to actual economic values ($REV_{1)}$ and one phenotypic standard deviation (REV_2).

Variables	REV_1	REV_2
Milk, kg	1	1
Fat, kg	12.60	20
Protein, kg	6.30	25.50

Results and discussion
Means, standard deviation (SD) and coefficient of variability (CV %) for the three variables studied are presented in Table 2. Means of 305 d MY, 305 d FY and 305 d PY were 2806 kg, 102 kg and 79 kg, respectively. The present means of the three variables were lower than those reported by **Kafidi et al. (1992), Atil and Khattab (2000), El- Awady et al. (2002), kadarmideen et al. (2003), Lazarevic et al. (2018), Amina Habib et al. (2020 and 2024) Estrada-León (2024) and Kassab et al. (2024)** worked on Friesian cows in different regions and ranged from 4490 to 9710 kg for 305 d MY , from 200 to 317 to for 305 d FY and from 158 to 296 to for 305 d PY. The variation in estimates of milk variables between our study and previous study may be due to the differences in breed composition, management, climate, feeding system, and models used in the analysis.
The CV % ranged between 33.82 to 35.97 % (Table 2). The estimates between 26.91 to 39.45 % for yield traits were reported **Amina Habib et al. (2020).** The higher CV % values of milk traits cause a great variation between individuals in important productive variables.

Estimates of direct heritability (h^2) for 305 d MY, 305 d FY and 305 d PY were 0.29±0.01, 0.24±0.02 and 0.29±0.02, respectively (Table 3). Our estimates are fall within the range calculated by many workers on different breeds of dairy cows in different regions. In this respect, Ahlborn and Dempfle (1992) with 178 Half-sib groups of 7345 Holstein – Friesian cows, stated that h^2 estimates for milk, fat and protein yield were 0.26, 0.26 and 0.28, respectively. El- Awady et al. (2002) with German Friesian cows, found that h^2 for 305 d MY, 305 d FY and 305 d PY were 0.32, 0.36 and 0.31, respectively. Rahayu et al. (2015) with Baturraden Dairy Cattle in Indonesia found that h^2 for MY, FP and PY were 0.20, 0.30 and 0.17, respectively. Uribe et al. (2017) with 64,029 complete lactation records of dairy cows in Southern Chile, using multi trait animal mode, found that h^2 estimates for milk yield, and fat and protein above 3% yield were 0.16±0.004, 0.44±0.007 and 0.42±0.006, respectively. Lazzrevic et al. (2018) worked on Holstein Friesian and Black and White cows, using mixed model, reported that h^2 estimates for MY, FY and PY were 0.291, 0.319 and 0.273, respectively. Amina Habib et al. (2024) with Holstein Friesian cows using MTAM reported that direct h^2 estimates for 305 d MY, 305 DFY and 305 d PY were 0.36, 0.30 and 0.23, respectively. While the present estimates are higher than those found by many authors. DeGroot et al. (2002) with Holstein cows, found that h^2 estimates for milk, fat and protein yield were 0.13 (0.02), 0.22 (0.08) and 0.09 (0.09) , they concluded that the small sample size could explain the small estimates of h^2 for milk and protein. El-Awady et al. (2002) with another set of that herd, using MTAM, found that direct h^2 estimates for MY, FY and PY were 0.017, 0.046 and 0.048. They concluded that lower estimates of h^2 could be due to higher percentage of permanent and residual environmental factors. Tohidi and Nazari (2023) with Iranian Holstein cattle, found that Heritability estimates using the repeated record animal model for 305 d MY, 305 d FY and 305 d PY were 0.19 ± 0.001, 0.15 ± 0.005, and 0.17 ± 0.006, respectively. Snedddon et al. (2015) worked on New Zealand dairy herds, using bivariate animal model, found that h^2 estimates for MY, FY and PY were 0.23+0.04, 0.15+0.04 and 0.14+0.03 respectively

Table 2. Means, standard deviation (SD) and coefficient of variability (CV%) for milk yield (MY), fat yield (FY) and protein yield (PY) in Friesian cows

	Means	SD	CV%
Milk yield (MY), kg	2806	949	33.82
Fat yield (FY), kg	102	37	35.97
Protein yield (PY), kg	79	28	35.46
No. of records 2181			

Table 3. Estimates of direct heritability (h^2_d) and repeatability (t) for 305 day milk yield (395 d MY), 305 day fat yield (305 d FY) and 305 day protein yield (305 d PY) for Friesian cows.

Variables	h^2_d	t
305 d MY	0.29±0.01	0.37±0.05
305 d FY	0.24±0.02	0.44±0.06
305d PY	0.29±0.02	0.51±0.06

Table 4. Additive genetic (rg), environmental (re) and phenotypic correlations (rp) for 305 day milk yield (305 d MY), 305 day fat yield (305 d FY) and 305 day protein yield (305 d PY) for Friesian cows.

Variables correlated	r_g	r_{pe}	r_e	r_p
305 d MY X 305 d FY	1.00	0.32	0.35	0.51
305 d MY X 305 d PY	1.00	0.14	0.34	0.52
305 d FY X 305 d PY	1.00	0.80	0.96	0.96

Standard errors ranged from 0.02 to 0.10

Repeatability estimates for 305 d MY, 305 d FY and 305 d PY were 0.37±0.05, 0.44±0.06 and 0.51±0.06, respectively (Table 3) and similar to those values reported by Tohidi and Nazari (2023) , being 0.38 ± 0.002, 0.34 ± 0.002, and 0.36 ± 0.002, for 305 d MY, 305 d FY and 305 PY, respectively.

The moderate h^2 estimates for milk, fat and protein yield, it can be concluded that the genetic improvement in milk yield and it is components can be achieved through selection breeding program, Also, According to moderate repeatability estimates for milk traits, culling of cows based on a single record as commonly practiced by commercial breeders of dairy cattle, would be recommended from a genetic standpoint.

Estimates of genetic correlations among the three variables were unity (Table 4) and were higher than phenotypic correlations which ranged from 0.50 to 0.96 (Table 4). Due to the high genetic correlations among milk yield and it is components, genetic selection for all traits can be achieved through selection for any of them. These results are agreement with previous studied (Ahlborn and Dempfle ,1992; Kafidi et al., 1992; DeGroot et al. 2002; El-Awady, 2002; Amina Habib et al. ,2020 &2024; Tohidi and Nazari (2023) and ranged from 0.68 to 0.995.

Estimates of direct additive genetic variance (σ^2a), permanent environmental variance, error variance (σ^2e) and phenotypic variance (σ^2p) and covariance among different variables which are used in construction selection indexes are presented in Table 5. Four selection indices were made according to REV_1 and REV_2 (Tables 6 and 7). The original index (I_1) included all the three variables (305 d MY, 305 d FY and 305 d PY), to be used for improving the aggregate genotype of the three variables, However, the reduced indexes (I_2, I_3 and I_4) include only two variables to select aggregate genotype.

For method 1 (REV_1) the expected genetic gain per generation in each variable (305 d MY, 305 d FY and 305 d PY) assuming a selection intensity 1 given in Table 6 . The expected genetic change per generation (EG) ranged from 285 to 305 kg for 305 d MY, from 12.22 to 14.0 kg for 305 d FY and from 10.41 to 11.93 kg for 305 d PY. Similarly for method 2 (REV_2) the expected genetic change per generation (EG) ranged from 285 to 305 kg for 305 d MY, from 12.22 to 14.0 kg for 305 d FY and from 10.41 to 11.93 kg for 305 d PY (Table 7).

Table 5. Estimates of (co) variance components for milk yield (MY), fat yield (FY) and protein yield (PY) for Frisian cows.

Estimates	Variables		
	MY	FY	PY
σ^2a	233103 (29%)	492 (23.64%)	358 (29%)
σa with MY		10709	9131
σa with FY			420
σ^2p_e	66527 (8.25%)	144(6.92%)	107(8.66%)
σp_e with MY		991	272
σp_e with FY			72
σ^2e	506780(62.75%)	1445(69.44%)	770(62.34%)
σ^2P	806419	2081	1235
σe with MY		21067	16422
σe with FY			1541

Table 6. Selection indices (I's) for different variables of Friesian cows, expected genetic changes per generation (EG) in each variable, correlation of index with aggregate genotype (R_{IH}) and the efficiency (RE) of different indices relatives to the original index (I_1) by using actual relative economic values (REV_1).

Indices	Variables						R_{IH}	RE%
	MY		FY		PY			
	b	EG	b	EG	b	EG		
I_1	0.3555	305	-9.2833	14.0	20.3613	11.93	0.63	100
I_2	0.3319	285	4.7620	13.1	----------		0.59	94
I_3	0.2368	298	----------		6.0717	11.67	0.62	98
I_4	----------		-3.6176	12.22	10.6254	10.41	0.55	87

Table 7. Selection indices (I's) for different variables of Friesian cows, expected genetic changes per generation (EG) in each variable, correlation of index with aggregate genotype (RIH) and the efficiency (RE) of different indices relatives to the original index (I_1) by using one phenotypic standard deviation (set_1).

Indices	Variables						R_{IH}	RE%
	MY		FY		PY			
	b	EG	b	EG	b	EG		
I_1	0.5680	305	-14.7984	14.0	32.4995	11.93	0.63	100
I_2	0.4033	285	5.78892	13.1	----------		0.59	94
I_3	0.3795	298	----------		9.7398	11.67	0.62	98
I_4	----------		-8.3589	12.22	24.6235	10.41	0.55	87

The present estimates are near similar to those reported by El- Awady et al. (2002) with German Friesian cow found that the expected genetic change per generation ranged between 338 kg and 344 kg for 405 d MY from 4.11 kg to10.81 kg for 395 d FY and from 7.55 kg to 7.98 kg for 305 d PY. Amina Habib et al. (2020) with another herd of Holstein Friesian cows reported that the expected genetic gain per generation ranged from 180 to 323 kg for 305 d MY, from 13.79 to 24.95 kg for 305 FY and from 13.79 to 24.95 kg for 305 PY). Ozturk et al. (2021) with Holstein Friesian cows in Turkey, found that the expected genetic gain for 305 d M was 111.5 kg/year. While Rahayu et al. (2015) with Indonesia cows found that the genetic gains of milk yield was 9.76 kg. Tohidi and Nazari

(2023) found that The regression coefficients of breeding values on calving years for 305 d MY, 305 FY and 305 DPY were 17.32 Kg, 0.51 Kg, 0.53 Kg, respectively.

The maximum genetic progress in 305 d MY, 305 d FY and 305 d PY was achieved by the original index (I_1) for both methods. The expected genetic gain in 305 d MY , 305 d FY and 305 d PY increased by 305 kg/generation, 13.0 kg/ generation and 11.93 kg/ generation, respectively (Tables 6 &7).

The index not including 305 d MY (I_4) showed a reduced accuracy (0.87) for both two methods. Therefore including 305 d MY with either 305 d FY or 305 d PY (I_2 and I_3) closed in accuracy to I_1 RIH (tables 6&7). Hence it would be desirable to include 305 d MY in an index incorporating 305 d FY and 305 d PY. Uribe et al. (2017) arrived at the same conclusion.

Compare of selection indices indicated that index I1, which incorporated 305 d MY, 305 d FY and 305 D PY and the third index I_3, which incorporated 305 d MY and 305 d PY are the best for both methods (R_{IH} = 0.98, Tables 6 &7).

The comparison of two methods of relative economic values revealed no differences among them for the economic gain (EG) of each trait, the relative importance hierarchy (R_{IH}), and the relative efficiency (RE) compared to the original index (I). Thus, the two methods effectively predicted the genetic gain per generation for the three traits under investigation. Therefore, it is recommended to use the second method, which involves one phenotypic standard deviation, as it is simpler to compute.

Conclusion

The present work suggested that the two methods of relative economic values predicted the genetic gain per generation for the three variables studied successfully and the second method (one phenotypic standard deviation) was recommended for ease of calculation

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Evaluation of Profitability and Cost-effectiveness of Rice Seeds Production among the Beneficiaries of KSADP/SAA in Kano State, Nigeria

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Abstract
This study was conducted to evaluate performance of rice seeds production among the beneficiaries of KSADP/SAA in Kano State. 156 community-based seed multipliers were randomly selected from 21 Local Government of Kano State. Structured questionnaire were used with the aid of android app kobocollect to collect the data for this study. Descriptive statistics, Cost estimation, Net profit, Operational ratio and Benefit cost ratio were used in the analysis of the data for this study. The study showed that seeds producers had a mean age of 45.27 years. Almost all (98.72% and 98.08%) of the respondents were males and married with a mean household size of 12. It was also found that 84.72% of them had a form of formal education and a mean years of experience in seeds production of 5.35 years. The results further revealed an average total cost of rice seeds production/ha of NGN571, 158.11. The revenue generated was NGN1, 743, 000.54 for with a net profit of NGN1, 171, 842.43. The return on investment on rice seeds production was 2.05. While the operational ratio was 0.29. The major challenges to rice seeds production were pest and diseases, unfavorable climatic condition and high transportation cost. It is concluded that rice seed production was profitable and cost-effective. It is recommended that researchers should refocus on development of high quality seeds that are resistant to drought and pest and diseases.

Keywords: *Profitability, rice, seeds, beneficiaries and Kano.*

Introduction

Agriculture is strategic to the Nigerian economy and plays a significant role of supplying food for the population, raw materials for industries, earning of high foreign exchange which is next only to that from crude oil, providing market for the industrial sector and a key contributor to wealth creation and poverty alleviation (National Seeds Policy (NSP), 2014). However, it is widely acknowledged that the most crucial tactic for increasing agricultural output and hastening the implementation of the National Food Security Programme is the deployment of higher quality crop cultivars by farmers for profitable farming (Ruma, 2008). Seed is widely considered as an essential ingredient for productive crop development. Farmers need enough high-quality seeds at the proper timing and cost to increase productivity (Umar, Sanni, Usman and Shu'aib, 2014). High-quality seeds help farmers meet their goals of increasing crop output and other applications (Chijoke and Akaninyene, 2019) and should be made readily available and effectively utilized to raise the standard of living of rural people and their income as well (Sapkota et al, 2018)

Therefore, as an alternative to the formal seed industry for distributing novel crop types, community-based informal seed manufacturing has grown in favour recently. This is due to the fact that most farmers can more easily get and afford farmer-produced seed than certified seed (Katuingi *et al*, 2011). To ensure regular supply of quality seeds at affordable price and poverty free society, some farmers were trained as community based seeds multipliers for which this study intended to describe the demographic variables, estimate the cost, revenue and profitability of rice seeds production and the possible challenges affecting rice seed production.

Methodology

Study Area

The survey area is Kano State, Nigeria. The State occupies an area of about 20,760 square kilometers out of which about 1,754,200 hectares of agricultural land and over 92,250 hectares of forest vegetation with a projected population of 13,969,085 (Male: 7,124,234 and Female: 6,844,852) (NPC, 2021). Kano State is located between latitudes 10˚ 30´N and 13˚02´N, and longitudes 8˚ 45´E and 12˚ 05´E. The State has a temperature ranging between 14.2˚C in January to about 40.3˚C in April being the warmest month with annual rainfall of 617mm. Relative humidity is high up to 80% in August, which drops to 23% in December and January. Two (2) major systems of crop production have been seen to be practiced in the State: the rain-fed and irrigation. Kano State is bordered by the States of Jigawa to the north and east, Bauchi to the southeast, Kaduna to the southwest, and Katsina to the northwest.

Sampling Procedure

Multi stage sampling technique was employed to select the respondents, in consideration of the SAA area of coverage and the seeds companies' area of coverage as well across gender. In the first stage, twenty-one (21) Local Government Areas of the State were purposively selected based on the intensity and preponderance of the beneficiaries of the SAA/KSADP. The LGAs selected include: Kura, Garunmallam, Tudunwada, Kumbotso, Gwarzo, Rogo, Danbatta, Kunchi, Tsanyawa, Dawakin Tofa, Bagwai, Kabo, Rimin Gado, Tofa, Minjibir, Ungoggo, Wudil, Warawa, Gezawa, Takai and Sumaila. List of the community-based seeds multiplication was sought from SAA. In the second stage, the sample frame obtained was used to generate the sample size by subjecting it to one of the Social Science research scientific sampling calculators that is Raosoft sample size calculator, at 95% confidence level and determined the sample size of 156 respondents. In the third stage, Simple Random Sampling was used to come up with the respondents.

Method of Data Collection

The data for this survey were obtained with the aid of structured questionnaire by well-trained enumerators in an android application kobocollect. Some of the information elicited include socioeconomic characteristics of the rice seeds producers (beneficiaries), costs of inputs used and output sold and the challenges encountered in rice seeds production.

Analytical Techniques

The analytical tools used in the analysis of the data for this study include descriptive statistics, cost and return estimation, net profit, operating ratio, benefit cost ratio and return on investment.

i. Cost estimation

Total cost = TVC + TFC …….... ……. (Equation 1)

Where:

TVC =Total Variable Cost associated with the seed multiplication (cost of seed, labour cost, watering, packaging etc) (₦)

TFC = Total fixed cost (₦)

ii. Return/total revenue generated

Total revenue (TR) represents the total income that farmers receive from selling the seeds to farmers. It comprises of the followings:

(i) Cash income is the value of sold products received in cash.

(ii) In-kind income is the value of the seeds for own usage, for charity or gift

TR = ∑ (income inflow in cash and in-kind)

Where: TR = Total Revenue (₦)

∑ = summation

iii. Net Profit

Net profit = TR – TC ……... (Equation 2)

Where:

TR = Total Revenue (₦)

TC = Total Cost of Seeds production/ha (₦)

iv. Benefit-Cost Ratio

Benefit-Cost Ratio (B/C ratio) is calculated by dividing the total present value of income earned after the activity by the total costs spent during the seed multiplication. The higher the value of operating ratio, the higher the profit margin. Hence, positive BC-ratio is always desirable and most recommended.

$$\text{Benefit} - \text{Cost Ratio (B/C ratio)} = \frac{\text{Total revenue}}{\text{Total costs}} \quad \text{……..... (Equation 4)}$$

v. Return On Investment (Return Per Naira Invested)

$$\text{ROI} = \frac{\text{Net profit}}{\text{Total cost}} \quad \text{……..... (Equation 5)}$$

Where: ROI = return on investment = return per Naira invested (₦)

vi. Operating Ratio

Operating Ratio: According to Eze *et al*., 2021, Operating Ratio measures how much profit is made after paying for variable cost. It is calculated using:

$$\text{OR} = \frac{\text{TVC}}{\text{TR}} \quad \text{……..... (Equation 3)}$$

Where: OR = Operating Ratio

TVC = Total Variable Cost associated with seed multiplication business

TR = Total Revenue generated after selling the seed produced

Results And Discussion

Socioeconomic Characteristics of CBSM Beneficiaries

The results of the socioeconomic characteristics of the community-based seeds multiplication beneficiaries are presented in Table 1 below:

Table 1: Socioeconomic characteristics of Community-based seeds multiplication beneficiaries

Variable	Category	Frequency	Percentage	Mean
Age of the CBSM beneficiaries				
	25 – 33	9	5.77	47.27
	34 – 42	44	28.21	
	43 – 51	56	35.90	
	52 – 60	40	25.64	
	61 – 69	7	4.49	
Gender of the beneficiaries				
	Male	154	98.72	
	Female	2	1.28	
Marital status				
	Single	3	1.92	
	Married	153	98.08	
Household size				
	1 – 8	49	31.41	12
	9 – 16	76	48.72	
	17 – 24	18	11.54	
	25 – 32	10	6.41	
	33 – 40	3	1.92	
Years of experience in seeds multiplication				
	1 – 5	109	69.87	5.35
	6 – 10	27	17.31	
	11 – 15	8	5.13	
	16 – 20	4	2.56	
	21 – 25	8	5.17	
Total		**156**	**100**	

Source: Survey data, 2023

Age of the CBSM beneficiaries: The results in Table 1 revealed that most (90%) of the CBSM beneficiaries were within the age group of 34 – 60 years, with average age of 47.27 years. This implies that majority of the CBSM beneficiaries of SAA/KSADP intervention were relatively young, agile with physical and mental ability to undertake seed multiplication enterprise as a business in the study area.

Gender and marital status of the beneficiaries: The results in Table 1 also showed that majority (98.72%) of the beneficiaries were males while the remaining 1.28 % were females. This indicated that seeds multiplication is male dominant and therefore, the CBSM program is highly gender biased, the need for incorporating many women is paramount as the business is very lucrative and therefore, alleviate poverty among gender. This finding agrees with Sakpota *et al*., 2017 who found that majority (74.2%) of maize seeds producers in Palpa District of Nepal were male. It was also found from the survey that majority (98.08%) were married.

Household size of the beneficiaries: Moreover, majority (80 %) of the CBSM beneficiaries had a household size of 1 -16 persons, with a mean household size of 12 denoting that the beneficiaries had a large household which is far greater than the national average of 5. It is obvious that large household size serves as a source of family labour which as a result, reduces cost of production and increase in the net income of the business.

Years of experience of the CBSM beneficiaries: The results in Table 1 further revealed that majority (70 %) of the beneficiaries had an experience of 1 – 5 years of seeds production, with an average experience of 5.35 years. This implies that the beneficiaries had some degree of experience in the business which will help them to have a good mastery of all the operations of the enterprise and to avert any form of risk associated with the enterprise as well.

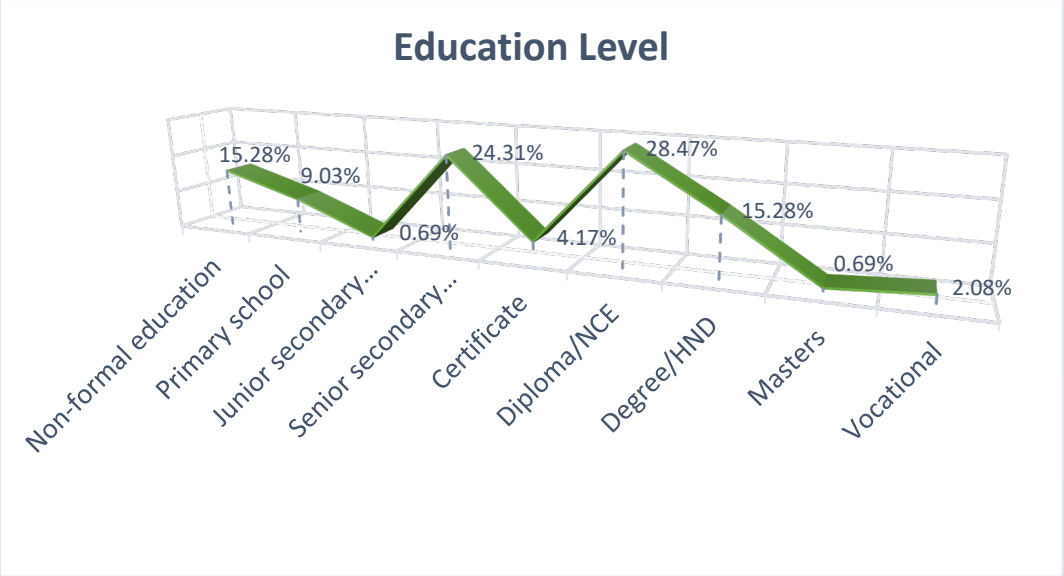


Figure 1: Educational level of the CBSM beneficiaries

Educational level of the beneficiaries: Figure 1 presents the educational level of the CBSM beneficiaries in the study area. 28.47% of them had diploma/NCE, 24.31% had attained SSCE certificate level, 15.28% each had a degree and non-formal education, 9.03% stopped only from primary school, 4.17% had certificate, 2.08% were vocational attendants and 0.69% each had junior secondary school and master's degree. This shows that majority (84.72%) of them had formal education which will assist them in reading instruction on chemical and fertilizer application and also in the adoption of innovation.

Cost Structure and Revenue of Rice Seeds Production among the Beneficiaries of KSADP/SAA in Kano State.

Rice seeds production incurred certain expenses of inputs and cost structure and revenue accrued from sales of rice seed are presented in Table 2 below:

Table 2: Cost structure and revenue of rice seed production among the beneficiaries of KSADP/SAA of Kano State

Rice seeds production			
Items	**Quantity (Kg/Ltr)**	**Amount (₦)**	**%TC**
Variable inputs			
Seeds	36.45	28,595.54	5.01
Fertilizer (NPK)	198.5	103,099.71	18.05
Fertilizer (Urea)	2	41,307.70	7.23
Fertilizer (USG)/Organic manure	75.7	26,062.45	4.56
Herbicides	4.71	18,301.69	3.2
Pesticides	2.19	8,710.55	1.53
Seed dress	5.92	1,796.48	0.32
Empty bags	54	14,530.86	2.54
Labour cost		253,703.80	44.42
Transportation cost		17,900	3.13
Loading and unloading		0.00	
Total variable cost		**514,009**	
Fixed inputs			
Depreciation on equipment		1,593.77	0.28
Rent		55,555.56	9.73
Total fixed cost		**57,149.33**	
Total cost of production		**571,158.11**	
Output			
Seeds	48.72	1,736,200.54	
Other grains			
Straw/Stover		6800	
Revenue		**1,743,000.54**	

Source: Survey Data, 2023

The results in Table 2 presents the cost structure and revenue of rice seeds production. The results showed a total cost of ₦571, 158.11 with an average revenue of ₦1, 743, 000.54. The results also revealed that labour constitutes the largest proportion of the total cost of rice seeds production (44.42%), followed by fertilizers (NPK, Urea and USG) which constitutes 29.84% of the total cost. While rent constitutes 9.73% and depreciation on equipment was the insignificant factor of rice seeds production with only 0.28%.

Profitability of Rice Seed Production among the Beneficiaries

Table 3: Profitability of rice seed production among the beneficiaries of KSADP/SAA

Items	Amount (₦)
Revenue	1,743,000.54
Variable cost	514,009
Total cost	571,158.11
Profit margin	67.23%
Net profit	1,171,842.43
Return on investment (RI)	2.05
Benefit cost ratio (BCR)	3.05
Operational ratio (OR)	0.29

Source: Survey Data, 2023

From the results in Table 3, there is an average revenue of ₦1, 743, 000.54 with a total cost of 571, 158.11. The net profit was estimated to be ₦1, 171, 842.43 with a margin of 0.6723 implying that profit constitutes 67.23% of the gross revenue. The benefit cost ratio was 2.05. This shows that for every ₦1 invested in rice seeds multiplication, all things being equal, there is a gross revenue of ₦2.05. The operational ratio of 0.29 implies that operating cost constitutes only 29% of the total revenue generated from rice seeds production while the remaining 71% is available to cover other cost such as interest, rent, premium etc. This shows that rice seeds production among the beneficiaries is cost effective.

Challenges Associated with Rice Seeds Multiplication

The community-based seeds multiplication beneficiaries are faced with various hitches affecting their seeds multiplication activities. The results for these challenges are presented in Figure 2 below:

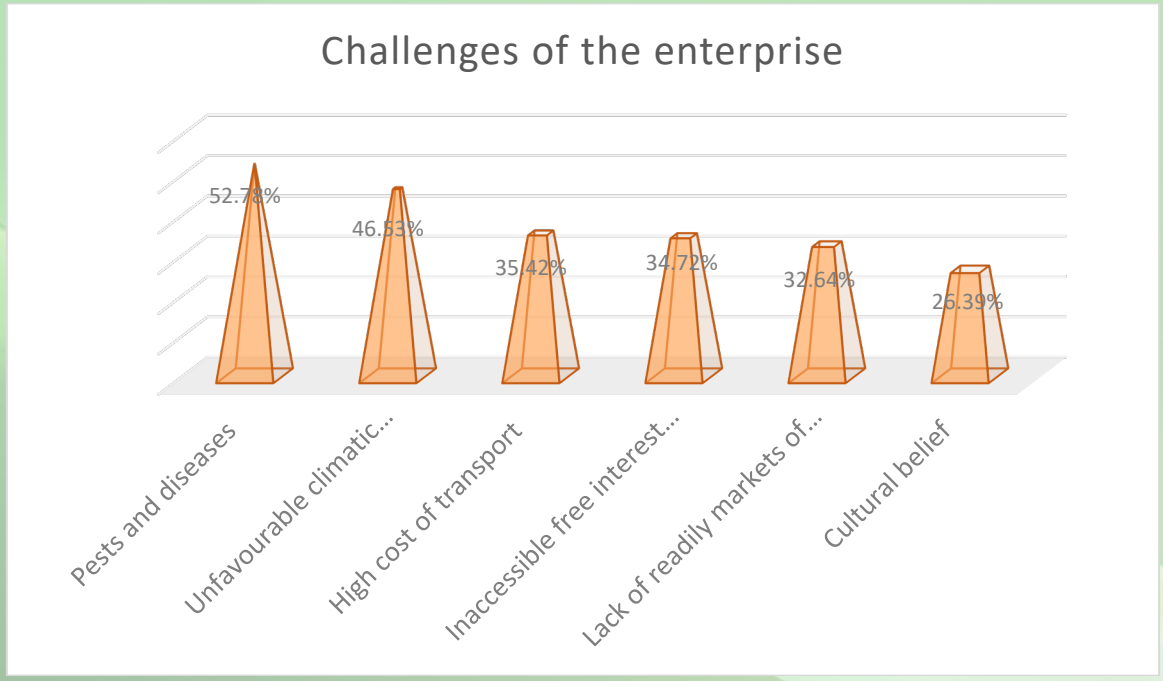


Figure 2: Challenges associated with community-based seeds multiplication (Multiple responses)

The results for the challenges of rice seeds production are presented in Figure 2 above. The results showed that 52.78% of the rice seeds producers (beneficiaries) indicated pests and diseases as one of the challenges affecting their seeds production activities, 46.53% reported unfavorable climatic condition, 35.42% and 34.72% reported high cost of transportation and inaccessible free interest loan respectively as their challenges, 32.64% showed lack of readily market of their product and finally 26.39% indicated cultural belief of the farmers to primitive seeds as their challenges to seeds multiplication enterprise.

Conclusion And Recommendations

Based on the findings of this study it can concluded that rice seeds production among the beneficiaries in the study area is a profitable enterprise and cost effectives. However, the enterprises is challenged by pests and diseases, unreliable climate and high cost of transportation. It is recommended that beneficiaries should adopt integrated pests management and climate smart production and also breeders should develop high quality seeds that are more resistant to pests and diseases and drought tolerant.

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ID: 713

Ameliorative Role of Dietary *Spirulina platensis* on Sumithion-Induced Growth Suppression and Intestinal Histopathological Alterations in Striped Catfish (*Pangasianodon hypophthalmus*)

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Abstract

Sumithion is commonly used pesticides to eradicate tiger bugs from aquaculture ponds; nevertheless, it adversely affects non-target species, particularly fish. The microalga (*Spirulina platensis*) could mitigate the sumithion-induced adverse effects in fish. Regarding this, the investigation was executed to mitigate the adverse effects of sumithion by Spirulina supplementation in diet to striped catfish (*Pangasianodon hypophthalmus*). During the 42-days experimental period, a total 240 of striped catfish fingerlings (10.82±1.34 g) were reared to four different treatments, including control, sumithion (0.6 mg/L), Spirulina (50g/kg feed at 3-5% body weight) and combined treatment (Spirulina + sumithion) with three replicates each. Sumithion treatment resulted in considerably decreased ($p<0.05$) the levels of FBW, GW and SGR (%/day) as well as increased FCR. In contrast to the sumithion treatment, the Spirulina treatment resulted in significantly ($p<0.05$) higher FBW, WG, and SGR (%/day), along with a lower FCR value. However, sumithion treated fish exhibited impaired structure of intestine and decreased the goblet cells and enterocyte number. In contrast, Spirulina either alone or with sumithion, significantly ($p<0.05$) improved intestinal structure, growth and feed efficiency. The present study unveiled the implementation of dietary Spirulina to be an effective approach to mitigate sumithion-induced stress and optimize health condition in striped catfish by improving histological index of intestine and growth indices.

Keywords: pesticides, toxicity, bioremediation, Spirulina, striped catfish

ID: 714

The impact of mineral nutrition, udder hygiene, and housing practices on subclinical mastitis under production conditions in Albanian dairy farms.[1]

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Abstract

Background and aim of study: Subclinical mastitis (SCM) represents a major health challenge in Albanian dairy farms; however, its management is frequently overlooked, characterized by limited diagnostic monitoring and a predominant reliance on conventional antibiotic-based treatments. Preventive strategies and awareness regarding abiotic risk factors—such as mineral nutrition, milking hygiene, and housing conditions—remain minimal, despite their well-documented role in the environmental transmission of mastitis pathogens. To date, few studies conducted in Albania have systematically investigated these factors. This study aims to assess the influence of key risk abiotic factors, namely mineral nutrition, milking hygiene, and housing conditions on the prevalence of SCM under real production conditions in dairy farms across various regions of Albania.

Methodology: The study was conducted on nine Holstein dairy farms in Albania, located in both lowland and hilly regions (herd sizes ranged from 21 to 140 cows; daily milk yields ranged from 12 to 30 kg). Data collection extended over an eight-month period during lactation. On each farm, a group of 6 to 10 cows in early lactation was randomly selected and monitored throughout all three stages of lactation. To evaluate the association between abiotic factors (mineral supply, udder hygiene, and housing conditions) and the occurrence of subclinical mastitis (SCM), no changes were made to existing farm management practices. Data were collected using a standardized protocol that included structured questionnaires on farm characteristics and feeding practices, as well as on-farm assessments of housing conditions, udder hygiene, and the application of the California Mastitis Test (CMT). Mineral content in feed samples was determined. Variance and regression analyses using SPSS were conducted to evaluate the influence of biotic and abiotic factors on SCM.

Results: The observed average prevalence of subclinical mastitis (SCM), defined as the percentage of cows with a CMT score of ≥1+ relative to the total number of animals tested, was 37.2% (range: 6–72%). This prevalence was significantly influenced by the level of mineral nutrient intake, assessed through the concentrations of Ca, P, Zn and Se per kilogram of dry matter (DM) intake (average daily DM intake of 20.9 kg/cow). Higher dietary Ca concentrations were significantly associated with a reduction in SCM prevalence ($P = 0.013$). An increase in Se concentration resulted in a quadratic decrease in SCM incidence ($P = 0.066$), while elevated Zn intake showed a trend toward reduced SCM prevalence. In contrast, P concentrations showed no effect on SCM occurrence. Udder cleanliness and teat infection status were both significantly associated with SCM occurence ($P = 0.01$ and $P = 0.001$, respectively). Post-milking teat disinfection demonstrated a highly significant effect in reducing SCM prevalence ($P = 0.001$). SCM occurrence was significantly lower in free-stall housing systems compared to tethered systems ($P = 0.001$). The use of stationary milking systems was also significantly associated with a lower prevalence of SCM compared to mobile milking units ($P = 0.001$).

Keywords: *subclinical mastitis; dairy cows; mineral nutrition; udder hygiene; housing conditions;*

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ID: 715

Amelioration of Microplastics-Induced Growth Inhibition and Stress in Nile Tilapia Using Multi-Species Probiotic

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Abstract

Microplastics (MPs) are emerging pollutants in aquatic ecosystems, known for their toxic effects on various physiological processes in fish. This study aimed to evaluate the potential of multi-species probiotics in mitigating the harmful impacts of MPs on Nile tilapia (Oreochromis niloticus). Fish with an initial weight of 3.02 ± 0.27 g were exposed to four treatment groups for 42 days: (1) control (no MP or probiotics), (2) MP exposure (10 mg/L), (3) probiotics only (1 ml/L), and (4) combined MP + probiotics. The results demonstrated that MP exposure significantly reduced growth performance and survivability, lowered haemoglobin levels, and increased glucose concentration in the blood. Additionally, erythrocytic cellular and nuclear abnormalities were more prevalent in the MP-treated group. Probiotic supplementation markedly improved these conditions by enhancing growth and survival and reducing haematological and cellular damage. Goblet cell frequency, which was reduced by MP exposure, was preserved in the probiotic-treated group. The relative mRNA expression revealed that MP exposure significantly upregulated antioxidant genes (*SOD* and *CAT*) and immune-related genes (*TNF-α*, *IFN-γ*, and *IL-1β*) in the liver. However, these expression levels were downregulated when probiotics were administered alongside MPs. Overall, the findings indicate that probiotics can alleviate microplastic-induced physiological stress and immune disruption, highlighting their potential as a protective dietary supplement in aquaculture.

Keywords: Microplastics, probiotics, growth performance, oxidative stress, immune response, Nile tilapia.

ID: 717

Ameliorative Role of Spirulina on Sumithion-Induced Hematological and Molecular Altarations in Nile tilapia

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Abstract

This study evaluated the ameliorative role of Spirulina in overcoming the adverse effects of the organophosphate insecticide sumithion on Nile tilapia (Oreochromis niloticus). Sumithion is extensively utilized in agricultural land and aquaculture ponds. The indiscriminate use poses a potential threat to many non-target organisms, including fish. For conducting the experiment, 240 Nile tilapia (O. niloticus) fingerlings, with an average weight (12.84 ± 0.09 g) were collected and randomly distributed in four treatments with three replications of each, namely T1 (Control), T2 (Sumithion; 0.3 mg/L), T3 (Spirulina; 50gm/kg), and T4 (Sumithion + Spirulina) for 42 days. According to the experimental outcomes, hemoglobin (g/dL) and blood glucose (mg/dL) levels were significantly ($p < 0.05$) altered in sumithion-treated fish. Regarding erythrocytic abnormalities, both cellular (teardrop, twin, spindle) and nuclear (nuclear buds, notched nuclei, karyopyknosis) abnormalities were most abundantly identified in sumithion-treated fish. Additionally, sumithion exhibited adverse effects on antioxidant and immune-related genes expression. In T2 (Sumithion), the expression of the antioxidant gene Superoxide Dismutase (SOD) was significantly ($p < 0.05$) downregulated, whereas the immune-related genes Tumor Necrosis Factor-alpha (TNF-α) and Interferon-gamma (IFN-γ) were significantly ($p < 0.05$) downregulated. However, Spirulina's protective role helped reverse the alterations that sumithion treatment induced. Consequently, Spirulina supplementation improved blood parameters, structure of erythrocytes, and expression of genes. The present study unveiled the implementation of dietary Spirulina to be an effective approach to mitigate sumithion-induced stress and optimize health condition in Nile tilapia by improving hemato-biochemical index and antioxidant-immune genes expression.

Key Words: *Aquaculture, Pesticides, Toxicity, Bioremediation, Spirulina, Nile tilapia*

ID: 718

Corporates' commitments from Net Zero to ESG Goal: Agri-Net Zero is the best pathway to attain Climate Action and Livelihood sustenance.

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Abstract

This paper presents Agri-Net Zero as the optimal pathway for corporate net zero compliance, emphasizing its dual role in advancing climate action while ensuring sustainable livelihoods. In the wake of accelerating climate change and the urgent need to stabilize global warming within critical thresholds, the integration of direct emission reductions and nature-based carbon sequestration in agricultural systems emerges as a transformative solution. Agriculture is highlighted as both a significant contributor to greenhouse gas emissions and a uniquely positioned sector capable of acting as a large-scale carbon sink. Through regenerative practices such as agroforestry, sustainable livestock management, and advanced soil health techniques, Agri-Net Zero enables corporations to achieve immediate and measurable decarbonization in line with stringent IPCC guidelines.

The paper examines global trends and corporate commitments to net zero targets and ESG goals, contextualizing the role of agriculture within broader mitigation strategies. It further presents the Clean Food Net Zero (CFNZ) program under the IBM-IORF Sustainability Project as a practical demonstration of the multifaceted impact of Agri-Net Zero. The CFNZ program's innovative "waste-to-wealth" strategy and integrated sustainability tools not only reduce greenhouse gas emissions significantly but also enhance energy efficiency, resource utilization, and overall economic viability.

By repositioning agriculture from an emissions-intensive sector to a critical component of the global carbon cycle, Agri-Net Zero provides a comprehensive, scalable, and economically viable model. This paper argues that through proactive adoption of Agri-Net Zero, corporations can bridge the gap between environmental imperatives and sustainable development, simultaneously achieving robust net zero compliance and bolstering food and livelihood security in a climate-uncertain future.

Key words : *Carbon sink, Waste to wealth, Net Zero, ESG, CFNZ program*

Introduction

Corporates' commitments to achieve net-zero emissions and advance robust ESG goals are emerging as a linchpin in the global effort to combat climate change and ensure sustainable livelihoods, with Agri-Net Zero at the forefront as a transformative pathway. Scientific consensus underscores that global temperatures, which have already risen by 1.1°C above pre-industrial levels between 2011 and 2020, must be capped at 1.5°C to 2°C by 2050 to avert devastating impacts, yet projections indicate a potential 2.8°C increase if current measures remain insufficient (WMO, 2024). Globally, nearly 9,000 companies have pledged to reduce emissions—with approximately 3,500 targeting net-zero outcomes—while Europe leads with 2,998 firms, Asia follows with 1,846, and the UK accounts for 702 companies committed to Science-Based Targets. In India, despite contributing roughly 7% to global emissions, 127 corporates have embraced net-zero targets under the ICRA ESG Ratings framework, signalling a burgeoning awareness, particularly as sectors such as power, energy, and cement lag behind (ET World, 2024). The drive toward net zero is not solely an environmental imperative; it is also fuelled by escalating investor pressure, anticipated regulatory shifts, and evolving consumer preferences that favor sustainability, all of which compel companies to innovate in renewable energy, energy efficiency, and sustainable supply chain practices. Notably, even as more than one-third of the world's largest companies have endorsed net zero commitments, analyses suggest that without at least doubling the current pace of emissions reduction by 2030, 93% are at risk of failing to meet their targets.

Agri-Net Zero presents an exceptionally compelling pathway for corporates to meet their net zero commitments because it directly tackles one of the most significant yet often under-addressed sources of greenhouse gas emissions—agriculture. Agriculture accounts for approximately 10–12% of global anthropogenic emissions, contributing around 16 $GtCO_2e$ in 2020 and projected to climb to 30 $GtCO_2e$ by 2050. This sector stands at a critical crossroads, being both the largest vulnerability to climate change and the second largest contributor to GHG emissions, yet it remains uniquely positioned to drive both adaptation and mitigation. By integrating innovative sustainable practices Agri-Net Zero can transforms farmlands into effective carbon sinks, thereby restoring the natural carbon cycle and enhancing soil health. Studies suggest that with the implementation of these

measures, potential CO_2 reductions in agriculture could range from 0.21 to 2.0 $GtCO_2e$ per year under various scenarios—gains that are critical for limiting global warming to below 2 °C by 2100. Moreover, as population growth and changing dietary preferences in developing economies drive up emissions further, agriculture's role in climate mitigation becomes even more urgent. With approximately 80% of countries incorporating agriculture into their mitigation targets and 64% including it in adaptation strategies via Nationally Determined Contributions, the Agri-Net Zero approach not only aligns with global climate objectives but also offers tangible benefits for corporates. It provides measurable progress on sustainability, mitigates supply chain risks for industries reliant on agricultural inputs, and supports innovation that can lead to improved resource efficiency and long-term financial benefits. In essence, by simultaneously reducing emissions from crop and livestock production, enhancing carbon sequestration, and restoring ecological balance, Agri-Net Zero delivers a comprehensive, scalable, and economically viable strategy that positions corporations as key drivers of climate action while securing food and livelihood security in an increasingly climate-uncertain world.

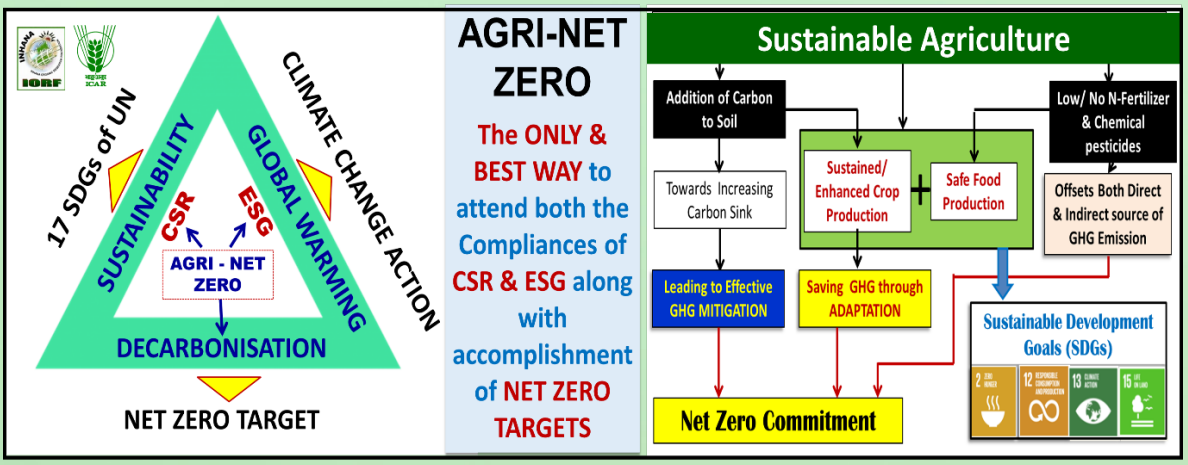


Fig 1 : Sustainable Agriculture can at a time attend the Net Zero Commitment & Sustainable Development Goals (SDGs)

Understanding Net Zero and Its Significance

The net zero concept represents a fundamental target in climate science and policy. It defines the state in which human-caused greenhouse gas (GHG) emissions are balanced by an equivalent amount removed from the atmosphere, effectively resulting in zero net emissions over multi-decadal timescales (IPCC, 2021). In essence, achieving net zero requires that every unit of CO_2 and other GHGs released by human activities is counterbalanced by removals through natural or engineered carbon sinks—such as forests, soil sequestration, or carbon capture and storage (CCS) technologies. This balance is critical because cumulative CO_2 emissions directly determine the extent of global warming. To keep warming within the 1.5°C threshold—an objective central to the Paris Agreement—the global carbon budget is estimated to be between 400 and 800 $GtCO_2$, implying that emissions must peak by 2030 and reach net zero by around 2050. Delays in reducing emissions not only erode the remaining carbon budget but also risk locking in long-term warming due to the persistent effect of CO_2 in the atmosphere.

Reaching net zero is both a scientific necessity and a moral imperative. Stabilizing global temperatures depends on halting the net addition of CO_2, while also addressing other potent, albeit shorter-lived, greenhouse gases like methane and nitrous oxide. The concept extends beyond a mere numerical target; it offers a comprehensive framework that demands aggressive, front-loaded emission reductions combined with rigorously verified removal strategies. A credible net-zero strategy is underpinned by several scientifically grounded attributes that ensure environmental integrity, equity, and effective climate action. First, emission reductions must be front-loaded, with immediate and substantial cuts to maximize the likelihood of limiting global warming to 1.5°C. Second, a comprehensive approach is required, addressing all emission sources, including those from hard-to-abate sectors such as heavy industry and agriculture. Third, reliance on carbon dioxide removal should be approached with caution, ensuring it does not detract from direct emission reduction efforts. Fourth, carbon offsets must be subject to stringent regulation to guarantee their environmental and social integrity, preventing misuse and ensuring real climate benefits. Fifth, the transition to net zero must be equitable, recognizing different national circumstances and providing necessary support to developing countries. Sixth, net-zero plans should align with broader socio-ecological objectives by integrating biodiversity conservation and sustainable development goals. Lastly, pursuing new economic opportunities through innovation and investment in clean technologies can drive sustainable growth and job creation. Together, these attributes form a robust framework for achieving net-zero emissions in a manner that is scientifically sound, socially just, and economically beneficial.

In summary, the scientific significance of net zero lies in its direct link to the global carbon budget and temperature stabilization. However, its practical implementation is a complex, multi-faceted process that bridges technological innovation, policy reform, and international cooperation. Adhering to this framework—with its emphasis on immediate, decisive action and robust verification—offers the most promising pathway to mitigate climate change and secure a sustainable future for all.

Agriculture's Dual Challenge of Sustainability and Climate Action

Agriculture occupies a central role in the global economy and environmental sustainability, underpinning human existence not only through its production of food but also by sustaining countless livelihoods. For example, in countries like India, roughly 60% of the population depends directly on agriculture, with about 80% of these individuals being small and marginal farmers (FAO, 2021a). This heavy dependency highlights both the vulnerability of the sector and its critical influence on driving equitable and sustainable development.

Unlike other sectors characterized by high emissions—such as energy, transport, or industry—agriculture's long-term sustainability is inherently linked to achieving net zero emissions. While many sectors can transition to cleaner technologies or switch energy sources without radically changing their operational models, agriculture relies directly on ecological stability, predictable weather patterns, and the overall integrity of natural systems (IPCC, 2023). Climate change imperils these essential foundations by increasing temperatures, altering precipitation patterns, intensifying extreme weather events, and facilitating the spread of pests and diseases. These threats not only jeopardize agricultural productivity but also intensify risks to global food security, making the pursuit of net zero a matter of survival rather than a mere environmental obligation.

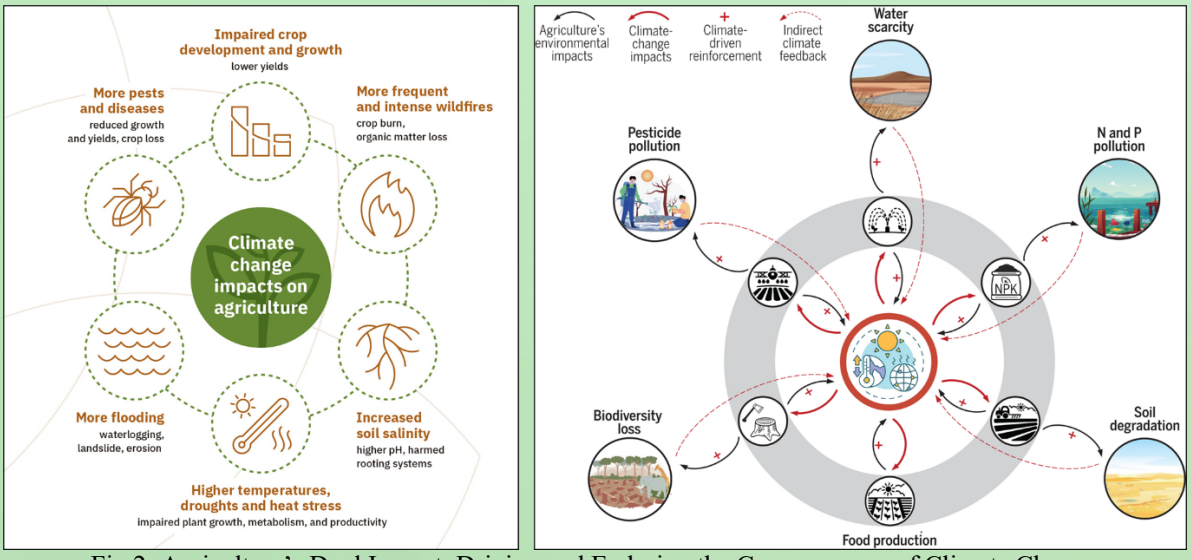


Fig.2: Agriculture's Dual Impact: Driving and Enduring the Consequences of Climate Change

Agricultural sustainability is also integral to achieving multiple Sustainable Development Goals (SDGs) such as Zero Hunger (SDG 2), Good Health and Well-being (SDG 3), Responsible Consumption and Production (SDG 12), Climate Action (SDG 13), and Life on Land (SDG 15) (United Nations, 2015). The sector now faces a dual challenge: feeding a growing global population—whose demand is projected to push food production up by approximately 50% by 2050 (FAO, 2017)—while simultaneously curbing its environmental impact. This tension is heightened in regions dominated by smallholder farming, where unsustainable practices have already emerged in agriculturally intensive and ecologically fragile areas.

Agriculture is uniquely positioned in the climate discourse; it is both a significant contributor to global greenhouse gas (GHG) emissions and one of the most vulnerable sectors to climate impacts. The sector is estimated to account for roughly 25–30% of global GHG emissions, primarily due to methane (CH_4) from enteric fermentation and rice paddies, nitrous oxide (N_2O) from synthetic fertilizer and manure applications, and carbon dioxide (CO_2) resulting from deforestation and land-use changes (IPCC, 2019). Moreover, the overuse of chemical inputs and extensive land conversion not only amplify emissions but also degrade ecosystems, reducing their capacity to act as natural carbon sinks (FAO, 2021). In India, for instance, agricultural activities contribute around 47% of total CH_4 and 80% of N_2O emissions, mostly from enteric fermentation, rice cultivation, and fertilizer use (MoEFCC, 2021; IPCC, 2019). These realities make it imperative to reform the sector—ensuring that the transition towards sustainable practices like climate-smart agriculture, agroecological methods, and improved resource management is supported by robust policy frameworks, financial investments, and international cooperation.

A promising aspect of agricultural ecosystems is their potential to mitigate climate change through soil carbon sequestration, with estimates suggesting that these systems could store up to 1 billion metric tons of carbon per

year—offsetting nearly 10% of global annual GHG emissions (Lal, 2020). However, this potential remains largely untapped due to the current lack of regenerative agricultural frameworks and the insufficient integration of carbon sequestration practices.

In summary, agriculture stands at a critical crossroads. It must navigate the dual imperative of meeting increasing food demands while drastically reducing its environmental footprint. The sector's decarbonization is not only a vital contribution to global climate goals but also a necessary path for its own longevity. By adopting deeply integrated strategies that encompass emission reductions, ecosystem restoration, and resilience-building, agriculture can pave the way for a sustainable future that concurrently addresses climate change and socio-economic development.

From Source to Sink: Repositioning Soil in the Climate Change Equation

Soil represents one of the largest natural carbon sinks on Earth, capable of storing more carbon than the atmosphere and terrestrial vegetation combined (Lal, 2004). This immense sequestration potential positions agriculture at the forefront of climate mitigation strategies, particularly in the context of achieving net zero. Agricultural soils, when managed sustainably, can absorb significant amounts of atmospheric carbon dioxide (CO_2) through processes such as enhanced organic matter input, cover cropping, conservation tillage, and agroforestry. However, conventional agricultural practices—characterized by intensive tillage, monocropping, and overuse of chemical inputs—have historically led to widespread soil degradation and carbon loss (IPCC, 2019). Transitioning to regenerative and climate-smart agricultural systems not only reduces ongoing emissions but also restores the soil's natural capacity to function as a long-term carbon sink. In this way, agricultural net zero initiatives go beyond short-term abatement; they contribute directly to the long-term stabilization of the climate system by embedding carbon back into terrestrial ecosystems. This dual functionality—emissions reduction and carbon sequestration—makes soil-centered agricultural strategies uniquely aligned with the IPCC's dual imperatives: curbing near-term warming and ensuring long-term climate resilience (IPCC, 2023). Hence, any credible pathway to net zero must prioritize agriculture not merely as an emitter to manage, but as a natural ally in climate restoration.

The IPCC Perspective: Positioning Agri-Net Zero within Net Zero Compliance Frameworks

The Intergovernmental Panel on Climate Change (IPCC) provides a foundational framework for achieving net zero emissions, emphasizing two core principles that are directly relevant to agriculture-based climate strategies. The first guideline identifies the need for an "entry point into longer-term emissions-reducing activities," stressing that any credible net zero compliance program must begin with immediate and significant reductions in absolute greenhouse gas (GHG) emissions—both direct and indirect (IPCC, 2023). This entry point is not merely about meeting near-term benchmarks but about initiating a robust and sustained trajectory of decarbonization. It necessitates the early adoption of mitigation strategies, investment in low-emission technologies, and structural shifts in policy and practice that drive continuous emission reductions over time. Agriculture offers a particularly strategic entry point in this context, given its potential not only to reduce emissions but also to serve as a large-scale carbon sink. Through integrated approaches that enhance both mitigation and sequestration, Agri-Net Zero emerges as a vital mechanism for aligning agricultural practices with net zero goals.

The second IPCC guideline focuses on the treatment of "impossible-to-abate" emissions—residual emissions from sectors where complete decarbonization is currently unfeasible due to technological or systemic limitations. In agriculture, this primarily includes methane (CH_4) emissions from enteric fermentation and nitrous oxide (N_2O) from fertilizer application and manure management, for which no zero-emission substitutes currently exist (IPCC, 2022). For these emissions, the IPCC framework mandates that carbon removals—whether through afforestation, soil carbon sequestration, or other nature-based solutions—be deployed judiciously and only as a compensatory measure for truly unavoidable emissions. Agri-Net Zero responds to this imperative by offering a responsible, science-aligned pathway that combines source-level emission abatement with landscape-scale sequestration. It prioritizes emissions reductions at the production level while leveraging the inherent carbon capture capacity of agricultural ecosystems. In doing so, it advances a balanced and ethically grounded net zero approach that neither delays mitigation efforts nor over-relies on offsets, but instead positions agriculture as a cornerstone in the global climate solution.

Emission Reduction Over Offsetting: Agriculture's Unique Decarbonization Advantage

In the pursuit of net zero, the global emphasis must shift from carbon offsetting mechanisms to actual emission reductions at the source. While many sectors rely heavily on offsetting—through afforestation, carbon trading, or external sequestration projects—to balance their emissions, these approaches often delay systemic change and create accountability gaps (IPCC, 2023). In contrast, agriculture stands out as a sector where internal emission reduction is not only viable but indispensable. Unlike sectors such as aviation or heavy industry, where decarbonization technologies remain limited or cost-prohibitive, agriculture offers a suite of nature-based and management-driven solutions that enable real-time reductions in greenhouse gas emissions (FAO, 2021c; Smith et al., 2019). These include practices such as improved livestock feeding strategies, reduced nitrogen fertilizer use, agroforestry, and enhanced soil carbon management—all of which lower emissions at the source while delivering co-benefits for biodiversity, soil health, and resilience. Therefore, agriculture represents a rare opportunity: a sector

capable of delivering authentic emission reductions without over reliance on external offsets. As climate accountability becomes more stringent, the credibility of agriculture's mitigation pathway—grounded in real emission reductions—positions it as a leading contributor to global net zero efforts.

Agricultural Net Zero: The Best Model for Achieving Climate and Sustainability Goals

Among the diverse pathways to net zero emissions, the agricultural net zero model offers the most holistic and achievable approach. Agriculture stands as the only sector where emission reductions, carbon sequestration, and sustainable land management practices can be integrated in a way that enhances food security, ecosystem services, and resilience to climate impacts. Unlike energy or industrial sectors that rely heavily on technological innovations or external carbon offsets, agriculture's capacity to both reduce emissions and actively cycle carbon back into the soil makes it an inherently productive, scalable, and natural carbon sink (IPCC, 2023; Lal, 2020). Regenerative agriculture, agroforestry, soil carbon management, and sustainable livestock systems provide a multi-pronged strategy that not only mitigates climate change but also regenerates vital ecological functions, such as soil health, biodiversity, and water management (FAO, 2021). Moreover, agriculture's direct relationship with food production ensures that net zero in agriculture is not an isolated goal but one deeply tied to global sustainable development targets—making it the most impactful and comprehensive net zero pathway. This synergy of climate action and food security makes agricultural net zero the best model for a sustainable future, combining environmental, social, and economic resilience in a single framework.

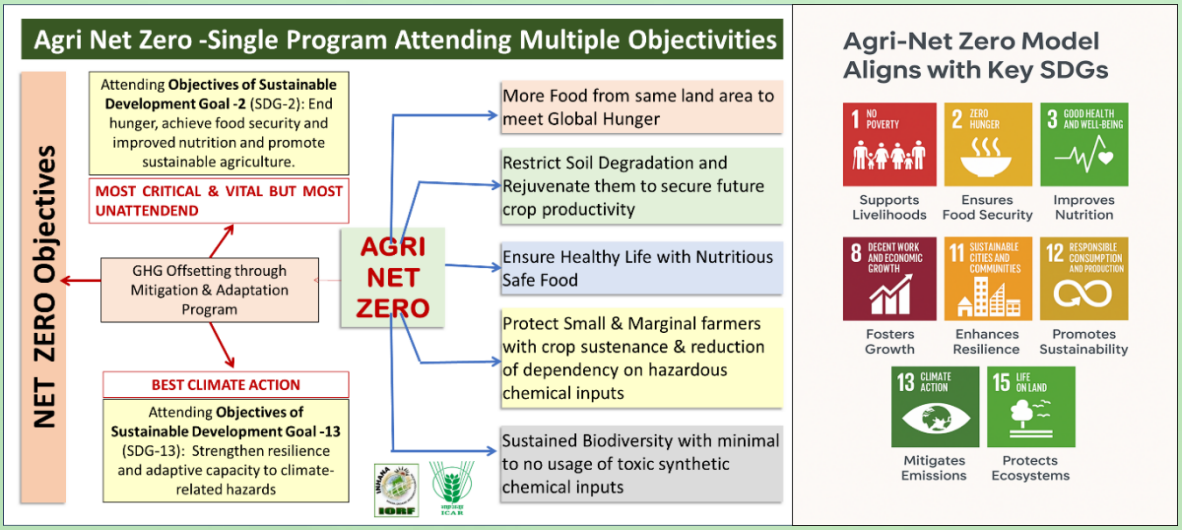


Fig.3: AGRI NET ZERO vital link in between Net Zero Objectives and Environmental & Social Goals

Agricultural Net Zero: The Only Pathway to Reintegration of Atmospheric Carbon

Among all major sectors, agriculture uniquely holds the potential not only to reduce emissions but to actively channel atmospheric carbon back into the terrestrial carbon cycle through biological processes. While sectors such as energy, transport, and industry focus primarily on reducing or avoiding emissions, agriculture—via soil carbon sequestration, biomass growth, and ecosystem restoration—can capture and utilize atmospheric CO_2 in ways that are intrinsic to its production system (IPCC, 2019a). Practices like agroforestry, regenerative tillage, organic matter incorporation, and pasture management serve as natural carbon drawdown mechanisms that reintegrate carbon into living systems and soils, where it contributes to soil fertility, water retention, and biodiversity (Lal, 2020). This makes agriculture the only sector where net zero is not solely an endpoint of balance, but also a functional mechanism for restoring the carbon cycle. Unlike engineered carbon capture, agricultural sequestration is inherently productive, cost-effective, and scalable—representing not just climate mitigation, but carbon utilization for long-term ecosystem and food system resilience. Achieving net zero in agriculture, therefore, offers the clearest pathway to align carbon removal with global sustainability and regenerative land use objectives.

Agri Net Zero: A Socially Inclusive Pathway for Livelihood Security and Rural Transformation

The Agri Net Zero can hold transformative potential not only for environmental sustainability but also for social equity and rural livelihoods. As agriculture continues to be the primary source of income for a majority of the rural population—particularly small and marginal farmers—transitioning to low-carbon, sustainable practices presents a unique opportunity for inclusive development (FAO, 2021). By promoting low-input farming systems that reduce dependency on expensive chemical fertilizers and pesticides, Agri Net Zero directly addresses rural indebtedness and economic vulnerability (World Bank, 2020). Moreover, the integration of regenerative and carbon-smart practices facilitates farmer participation in emerging carbon markets through carbon farming initiatives, creating new income streams via carbon credits (IPCC, 2023; Verra, 2022). In addition, the Agri Net Zero framework aligns

with national and global food security goals by improving soil fertility, ensuring year-round productivity, and enhancing the nutritional value of food outputs. These systemic improvements contribute to SDG-2 (Zero Hunger), SDG-1 (No Poverty), and SDG-10 (Reduced Inequalities), among others. Furthermore, empowering farmers with climate-smart knowledge and market access strengthens community resilience and fosters rural development through decentralized, sustainable economies. Thus, beyond emissions reduction, the Agri Net Zero model emerges as a powerful socio-economic lever for driving rural transformation, food system resilience, and equitable climate action.

Agri Net Zero: Pioneering Sustainable Agriculture for a Resilient, Net Zero Future

Agri Net Zero is the optimal net zero strategy because it addresses the twin imperatives of limiting global warming through direct emissions reduction and mitigating climate change by transforming sectors that are both major emitters and potential carbon sinks. The core net zero objectives emphasize reducing greenhouse gas (GHG) emissions from human activities and mitigating the broader impacts of climate change; however, since corporations cannot realistically achieve a 100% reduction across Scope 1, 2, and 3 emissions, they must rely on advanced technological interventions and strategic offsetting measures. Agri Net Zero leverages this approach by focusing on agriculture—a sector that, while responsible for substantial GHG outputs such as nitrous oxide and methane, also possesses the unique capacity for carbon sequestration through improved soil health, regenerative practices, and precision farming. Guided by IPCC recommendations, the strategy prioritizes decarbonization in areas where emissions are particularly challenging to abate and emphasizes long-term, sustainable measures that extend beyond short-term fixes. Moreover, Agri Net Zero not only enhances crop sustainability by reducing the reliance on chemical inputs like nitrate fertilizers but also integrates circular economy principles by converting agricultural waste into resources, effectively transforming the sector into a carbon-negative system. This approach is especially critical given that a significant portion of the global population—up to 70% in countries like India—relies on agriculture for their livelihoods, with a large percentage of small, resource-poor farmers at risk from the impacts of climate change. By aligning with Sustainable Development Goals such as SDG 13 (climate action) and SDG 2 (zero hunger), Agri Net Zero ensures that corporate efforts toward emissions reduction are simultaneously advancing social, economic, and environmental sustainability. In essence, Agri Net Zero integrates robust technological solutions, long-term ecological benefits, and comprehensive social responsibility, making it the most viable and impactful approach for achieving a resilient net zero future.

Practical Demonstration of Agri-Net zero Model- Clean Food Net Zero (CFNZ) Program under IBM-IORF Sustainability Project (2021-22 to 2023-24)

The IBM-IORF Sustainability Project (2021–22 to 2023–24) has successfully demonstrated a breakthrough Agri-Net Zero model through its Clean Food Net Zero (CFNZ) Program, which integrates nature receptives agronomic innovations for sustainable, pesticide-free, and carbon-negative food production. Developed by the Inhana Organic Research Foundation on the proven ECCES Model, the CFNZ model leverages IRF Technology for Plant Health Management—providing 360° support from seed treatment to production and enhancing crop productivity by up to 20%—in tandem with Novcom Composting Technology for Soil Health Management. Comprehensive field evaluations have shown that this integrated approach not only reduces the cost of cultivation through optimized resource utilization and enhanced plant immunity but also significantly improves energy efficiency, with recorded gains upto 432% higher crop productivity per unit energy investment and a 57% energy transition.

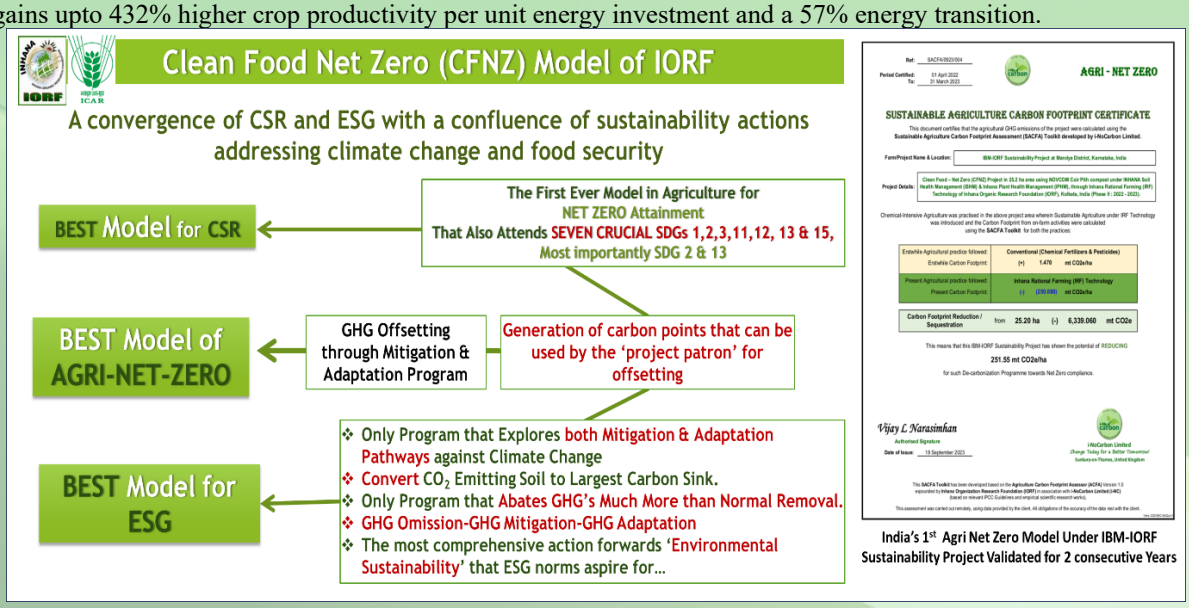


Fig 4 : The Clean Food Net Zero (CFNZ) program, under the IBM-IORF Sustainability Project, effectively showcased the extensive, multifaceted impact of the Agri-Net Zero model.

A pivotal innovation within the program is its "waste-to-wealth" strategy, wherein the conversion of coir pith—a byproduct of the coconut industry into Safe–Stable–Mature Compost can mitigate up to 250 MT CO_2e per hectare by transforming a high-methane-emitting waste into a valuable organic manure, thereby reducing methane emissions and enhancing soil organic carbon sequestration. Demonstrations on model farms in West Bengal and Karnataka revealed that a 100-hectare application of the CFNZ model can potentially offset between 24,833 and over 50,000 MT CO_2e per year, Furthermore, the project has developed unique sustainability tools viz. the Soil Health Proximity Model, the Pesticide Pollution Index, and the Carbon Footprint Indices—that provide quantitative assessments of soil quality, pesticide risk, and crop sustainability. By aligning with multiple Sustainable Development Goals (notably SDG 2 and SDG 13) and complementary government initiatives such as the Agriculture Accelerator Fund, GOBARdhan etc, the CFNZ model paves the way for transforming conventional, GHG-emitting agricultural practices into resource-independent, GHG sink systems, with scalable potential to register carbon abatement and to significantly contribute to corporate, net zero, and sustainability compliance in the agricultural sector.

Conclusion

Agri-Net Zero stands out as the best model for Corporate net zero compliance by seamlessly integrating direct emission reductions with nature-based carbon sequestration. This approach transforms agricultural landscapes—one of the most significant sources of greenhouse gas emissions—into dynamic carbon sinks, while concurrently enhancing soil health, ensuring food security, and mitigating supply chain risks. Unlike traditional offsetting methods that often delay systemic change, Agri-Net Zero implements regenerative practices such as agroforestry, sustainable livestock management, and advanced soil techniques that drive immediate and measurable decarbonization. Aligned with rigorous IPCC guidelines, this model tackles both direct emissions and "impossible-to-abate" emissions like methane and nitrous oxide through innovative, sustainable strategies. The practical success of initiatives like the Clean Food Net Zero Program under the IBM-IORF Sustainability Project further demonstrates its scalability, economic viability, and the substantial environmental co-benefits it offers—ranging from improved energy efficiency to significant cost reductions in resource utilization. By directly addressing emission reductions at the source and securing sustainable livelihoods for communities, Agri-Net Zero not only helps corporations meet their ambitious net zero targets but also reinforces their overall ESG commitments. In an era where rapid climate action is essential, Agri-Net Zero provides a transformative and comprehensive pathway that uniquely positions agriculture as a cornerstone in the global pursuit of climate stability and sustainability.

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ID: 719

Impacts of Salinity Stress on the Physiology and Tissue Structure of Nile Tilapia

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Abstract

Salinity is considered one of the most important environmental factors, and stress induced by salinity negatively impacts aquaculture production. This study focused on hematological and histological alterations induced by different salinity levels in Nile tilapia (*Oreochromis niloticus*). The experiment was carried out with a total of 300 fingerlings exposed to 5 different treatments: T1 (control), T2 (3 ppt), T3 (6 ppt), T4 (9 ppt), and T5 (12 ppt) with three replicates each, over 42 days. The study revealed that hemato-biochemical parameters (hemoglobin and glucose) levels were increased at 9 and 12 ppt compared to the control. Regarding erythrocytic abnormalities, cellular (fusion, twin, teardrop, spindle) and nuclear (nuclear bridge, binuclei, notched nuclei, karyopyknosis) abnormalities were significantly more abundant in T4 and T5 compared to other treatments. Histological examination showed that the abnormalities of gills (epithelial lifting, hypertrophy of chloride cell, telangiectasia, deformed pillar system, hyperplasia), liver (hepatocyte hypertrophy, hemorrhage, blood congestion, hemosiderin, melano-macrophage centers), kidney (necrosis, shrinkage of renal corpuscle, hemorrhage, glomerular destruction, melano-macrophage centers) were found in 9 ppt, but markedly alterations were detected at 12 ppt with increasing the days of exposure. These findings are projected to be valuable in raising awareness about the importance of salinity levels for freshwater aquaculture species.

Key Words: *Salinity, Stress, Hematology, Histology, Tilapia*

ID: 720

Growth and Feed Utilization Responses of Nile Tilapia (*Oreochromis niloticus*) to Microplastics and Sumithion Co-Exposure

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Abstract

The widespread contamination of aquatic environment by microplastics (MPs) and chemical pollutants, including pesticides, pose a severe threat to aquatic organisms, leading to significant disruption in ecological health. This research investigates the cumulative toxicity of polyamide microplastics and the organophosphate pesticides sumithion on Nile tilapia (*Oreochromis niloticus*), a widely cultivated freshwater key species. Over the course of 42 days, the fish were subjected to three treatment groups; 10 mg/L microplastics, 0.3 mg/L sumithion, and a combined exposure to both microplastics and sumithion (MP + Sum). This investigation focused on evaluating growth parameters and tissue histopathology. Co-exposure to microplastic and sumithion led to a significant reduction in growth attributes including final body weight, weight gain, and specific growth rate (SGR), while feed conversion ratios increased, suggesting diminished feed efficiency. The histopathological changes observed in the intestinal tissues including degeneration of columnar epithelium, hyperplasia of intestinal mucosa, degeneration of lamina propria from epithelium, reinforced the severity of the combined exposure. The GH, IGF1, and IGF2 gene expression in Nile Tilapia exibited a consistent downward trend, where the control group exhibits the highest level, followed by a significant reduction in response to microplastic exposure, a further decline under Sumithion treatment, and the most profound suppression in the combined exposure group, detrimentally affecting the growth and development. Overall, the results of the present study highlights the urgent need for integrated approaches to pollution management in aquatic ecosystems to mitigate these synergistic effects.

Keywords: *Microplastics, Sumithion, Nile tilapia, Growth, Histopathology, Gene Expression.*

ID: 724

Algorithms And Analytics: An Advantage For Data-Driven Decision-Making In Global Marketing And Trade

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Abstract

In an increasingly interconnected global marketplace, the role of mathematics and data-driven strategies in shaping marketing and trade decisions has become indispensable. As e-commerce expands across borders and consumers shift toward digital engagement, businesses that leverage quantitative tools such as predictive analytics, optimization models, and machine learning algorithms are achieving strategic advantages. This paper explores how data-based methodologies are redefining global marketing and international trade dynamics in a rapidly globalising and technologically fluid environment. The paper provides a literature-driven foundation on the intersection of mathematics, data science, and global commerce, followed by a discussion on emerging practices, such as personalized marketing, dynamic pricing, inventory optimization, and real-time consumer behavior analysis. Case studies from global brands illustrate how mathematical tools enable better market segmentation, trade forecasting, and cross-border supply chain efficiency. The paper further argues for a more integrated role of data science in business curricula and policy frameworks, especially in emerging markets, where digital transformation is creating new opportunities. A shift toward data-driven global strategies not only enhances profitability but also supports more sustainable, inclusive, and responsive trade ecosystems. In the context of and food marketing systems, African farmers and and food marketers can adopt algorithms and data analytics to enhance market access, optimize production, improve supply chain efficiency, and make informed decisions that align with global trade demands.

Keywords: Algorithms, Analytics, Data driven, decision making, global marketing, trade

Introductıon

Global trade and marketing are no longer the domains of intuition and experience alone. In today's hyper-connected, data-saturated world, business strategies are increasingly informed—and in many cases, driven—by mathematics and algorithmic decision-making (Yazdi, 2024; Aneesha, 2024). From personalized recommendations on Amazon to dynamic pricing models in global airlines, data has become both a resource and a strategic compass. As digital platforms break down geographical barriers, the scale and complexity of international marketing demand robust quantitative tools (Addy et al., 2024). Simultaneously, global trade is affected by volatile consumer trends, supply chain disruptions, and geopolitical shifts—requiring companies to react with precision and speed (Celestin & Sujatha, 2024).

Mathematics plays a critical role in navigating this complexity. Algorithms enable customer clustering and sentiment analysis; optimization models streamline logistics; statistical tools support market research and predictive modeling; and machine learning algorithms allow businesses to adapt to shifting demand in real time (Rane et al., 2024).

In this paper, we aim to demonstrate the growing convergence of mathematical thinking and global commerce. The study surveys the relevant literature, then delves into contemporary applications in global marketing and trade, and concludes with practical insights and policy recommendations for businesses and institutions aiming to remain competitive in a data-driven global economy.

Mathematical Foundations of Decision-Making in Business

Mathematics forms the backbone of modern business decision-making. Tools like linear programming, decision theory, and game theory help optimize resource use and strategic choices, while trade models such as general equilibrium and gravity models simulate global trade flows (Bahiraie *et al*., 2024; Anderson & van Wincoop, 2003). In global marketing, the explosion of big data has fueled predictive analytics, enabling firms to mine insights using clustering, regression, and association rules (Han, Kamber & Pei, 2012). Machine learning techniques such as neural networks and decision trees support customer segmentation, churn prediction, and personalized targeting (Sharma & Lambert, 2021).

E-commerce giants like Amazon and Alibaba leverage collaborative filtering and matrix factorization for algorithmic personalization (Linden, Smith & York, 2003), while dynamic pricing models respond to real-time data shifts (Elmaghraby & Keskinocak, 2003). In supply chains, mathematical models like EOQ and the

newsvendor model improve inventory and logistics (Bazan *et al*., 2016), with AI-enhanced systems now forecasting disruptions and optimizing freight in real time (Ivanov & Dolgui, 2020).

Despite these advancements, ethical concerns are rising. Scholars warn of algorithmic bias, data privacy issues, and cultural insensitivity, especially in emerging markets (Eubanks, 2018; Noble, 2018). Algorithms trained on Western datasets may misrepresent diverse consumer behaviors, underscoring the need for inclusive and culturally informed models. As businesses become increasingly data-driven, ethical and localized approaches are vital for effective and equitable global marketing. This perspective has been illustrated in Figure 1.

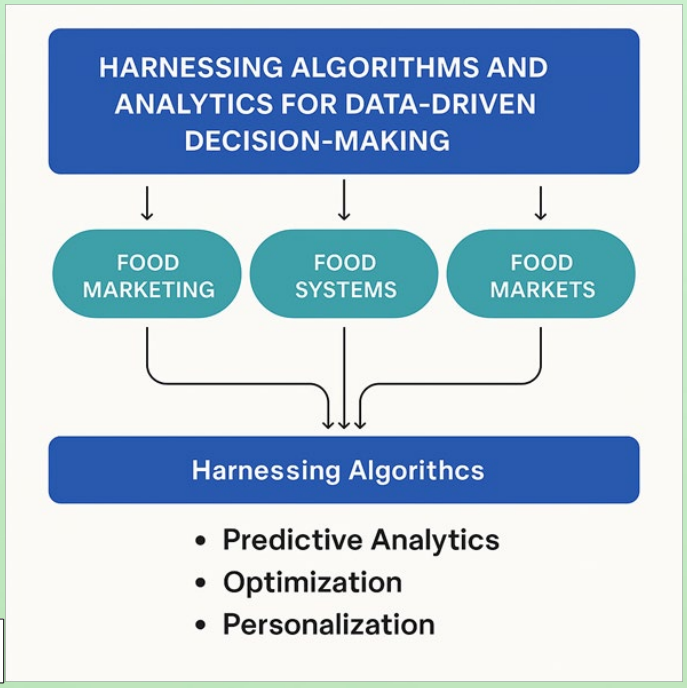


Figure 1. Authors' Proposed Framework

Figure 1, shows a framework highlighting how algorithms and analytics are transforming decision-making in food marketing and trade. Predictive tools and optimization models boost efficiency, forecast demand, and tailor strategies to consumer needs. Data-driven insights enhance policy, investment, and sustainability in agriculture. As data becomes foundational to global competitiveness, firms must invest in ethical, inclusive strategies, infrastructure, and culturally aware modeling to stay ahead.

The intersection of mathematics and global business is no longer optional, it is foundational. Companies that fail to adopt data-driven strategies risk falling behind in a world where agility, personalization, and efficiency define competitiveness. Yet, these strategies must also be inclusive and ethically grounded, ensuring that data use does not exacerbate inequality or erode consumer trust. Investing in data literacy, infrastructure, and culturally informed modeling is essential for both multinationals and local firms aspiring to compete globally. The practical application of mathematics in business decision-making is further illustrated below.

Price Forecasting using Basic Algorithm and Analytics

This section presents a simple illustrative example using a basic algorithm and analytics in the context of price prediction and market decision-making in global marketing and trade, particularly for agricultural exports from Africa.

Illustration: Price Forecasting Using Linear Regression (A Simple Algorithm)

Objective: Predict future export prices of cocoa based on historical data using a linear regression model.

Step 1: Historical Data (Simplified)

Assuming the following data for export prices of cocoa over 5 years, as presented in Table 1.

Table 1 Hypothetical Export Prices of Cocoa between 2020 and 2024

Year	Export Price (USD/ton)
2020	2,200
2021	2,300
2022	2,450
2023	2,600
2024	2,750

Source**:** Hypothetical dataset c*onstructed by authors for illustrative purposes.*

Table 1 presents hypothetical data set generated by the authors to illustrate the application of linear regression in predicting export prices.

Step 2: Apply Simple Linear Regression

The general formula of a linear regression model is:

$$y = a + bx$$

Where:

- y = predicted price
- x = year (treated numerically, e.g., 1 for 2020, 2 for 2021...)
- a = intercept
- b = slope

From the data, we calculate:

- Mean of x = 3
- Mean of y = 2,460

$$b = \frac{\sum(x - \bar{x})(y - \bar{y})}{\sum(x - \bar{x})^2}$$

$$b = \frac{(-2)(-260) + (-1)(-160) + (0)(-10) + (1)(140) + (2)(290)}{(-2)^2 + (-1)^2 + 0^2 + 1^2 + 2^2}$$

$$b = \frac{520 + 160 + 0 + 140 + 580}{4 + 1 + 0 + 1 + 4} = \frac{1400}{10} = 140$$

$$a = \bar{y} - b\bar{x} = 2400 - 140(3) = 2460 - 420 = 2040$$

Prediction Model:

$$Price = 2040 + 140x$$

Step 3: Using the Algorithm for Decision-Making

Predict export price in **2025** (i.e., x=6):

$$Price_{2025} = 2040 + 140(6) = 2040 + 840 = USD2{,}880\ per\ ton$$

From the result, this simple model can help decision-makers to:

- Forecast future prices for planning production and marketing
- Advise farmers on when to harvest or sell
- Inform export contracts and trade negotiations

This illustration demonstrates that such algorithmic insights, when scaled and refined with real-time analytics, can give African farmers and marketers a strategic edge in global trade.

Applications and Case Studies

Global companies use mathematical tools to transform business: Alibaba analyzes demand trends with AI, Unilever optimizes supply chains using machine learning, and Amazon and Walmart apply predictive analytics for logistics and promotions. In Africa, Jumia leverages mobile data to reach underserved markets, guiding vendor engagement and logistics through insights from consumer behavior. These applications are illustrated in Figure 2.

Figure 2 illustrates how data-driven decision-making in global marketing and trade relies on predictive analytics, optimization models, and machine learning. These approaches support personalized marketing, inventory optimization, and trade forecasting with segmentation—enabling strategic advantage in a rapidly changing world.

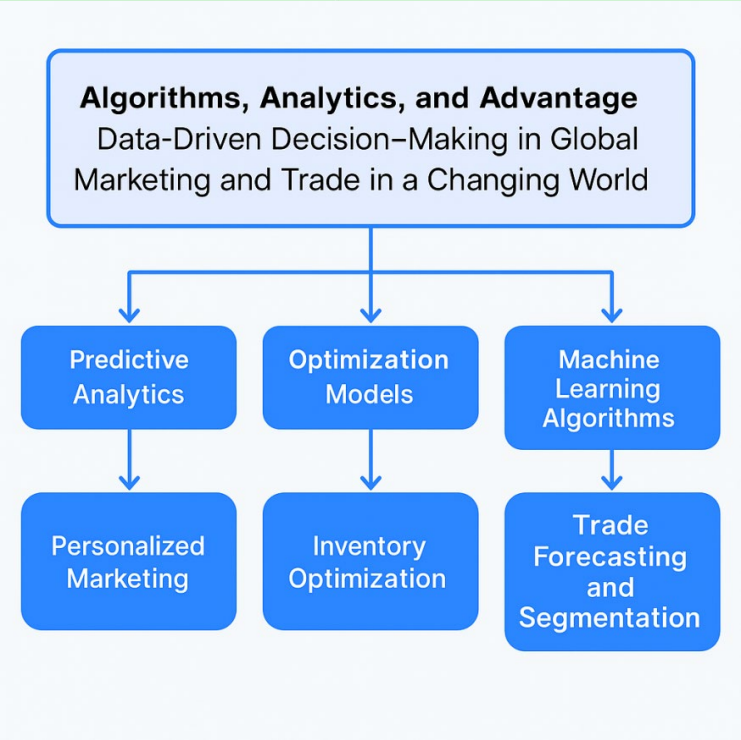


Figure 2. Authors' Proposed Framework

Algorithms, Analytics and Food Marketing Systems

The integration of algorithms and analytics into food systems has transformed how decisions are made across food marketing and trade. Recent studies underscore the pivotal role of data analytics in enhancing efficiency, transparency, and responsiveness within agri-food value chains (Klerkx & Rose, 2020). Predictive analytics and machine learning algorithms are now widely used to forecast consumer trends, optimize supply chains, and tailor marketing strategies in real time (van der Burg *et al*., 2019). In food marketing, big data enables segmentation and personalization, helping businesses respond to diverse consumer preferences, ethical concerns, and sustainability demands.

Moreover, in global food markets, algorithms support price prediction, demand estimation, and trade logistics, facilitating smarter and faster decision-making (Zhong *et al.*, 2020). For food systems, analytics contribute to risk management, climate resilience, and resource optimization by analyzing large datasets from farm-level sensors, satellite imagery, and market reports. As a result, digital intelligence enhances the adaptability of food systems in the face of volatility and global shocks. However, literature also highlights challenges such as data quality, digital inequality, and ethical considerations in algorithmic governance. Addressing these issues is essential to fully harness the benefits of analytics for inclusive and sustainable food system transformation. The framework illustrating how algorithm and data-analytics facilitate global marketing is shown in Figure 3.

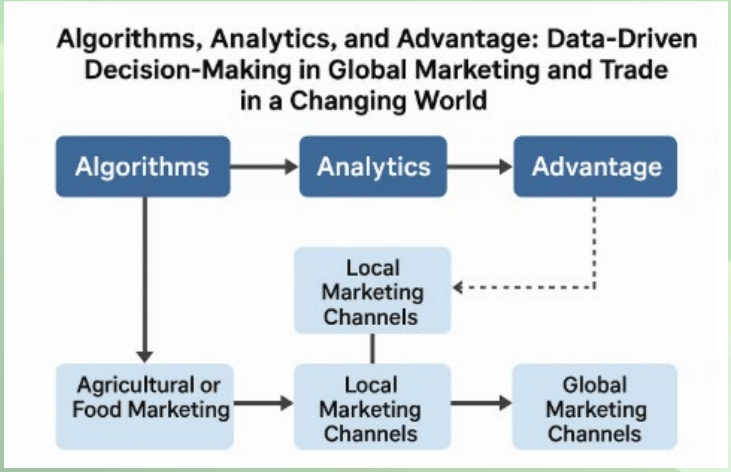


Figure 3. Authors' Proposed Framework

Figure 3 illustrates a dynamic, data-driven framework linking algorithms, analytics, and competitive advantage within the context of agricultural or food marketing. Algorithms initiate the process by generating insights from raw data, which are then processed through analytics to inform strategic decisions. These analytics support both local and global marketing channels by optimizing supply chains, identifying market trends, and enhancing consumer targeting. Agricultural marketing, as the entry point, is positioned to benefit from these insights, ensuring better market alignment. Local marketing channels serve as a crucial feedback loop, where real-time data informs further refinement of algorithms and strategies. This interaction enables producers especially farmers to scale operations, penetrate global markets, and adapt to changing trade environments. The framework emphasizes a continuous cycle of improvement, where informed decision-making leads to sustainable competitive advantage, fostering inclusive participation of African farmers in global trade networks.

Role of Algorithms and Data Analytics in Shaping Food Marketing in Africa

Food marketing in Africa has traditionally been localized, with most farmers relying heavily on product exchange at the farmgate. Therefore, leveraging algorithms and data analytics becomes essential to advance food marketing beyond the farm gate and into the global marketplace. The transformation of food marketing in Africa is increasingly driven by data and digital innovation. Traditional, fragmented supply chains are being reshaped by mobile platforms and algorithmic tools that enhance access to global markets. ICT plays a key role in connecting rural producers to international buyers (Aker, 2010; World Bank, 2020). Platforms like Twiga Foods and FarmCrowdy use real-time data and algorithms to optimize logistics, reduce waste, and improve pricing. Blockchain and traceability tools help meet global standards, fostering trust and market expansion (Kamilaris *et al*., 2019). Predictive analytics support inventory management, export forecasting, and targeting of niche markets (FAO, 2021; UNCTAD, 2022). However, challenges like digital divides and low data literacy persist, risking the exclusion of smallholders. Inclusive data ecosystems and public-private partnerships are essential to ensure equitable participation. Overall, data and algorithms serve as strategic enablers, positioning African food systems for global competitiveness.

Conclusion

In today's dynamic global landscape, mathematics and data science are essential for strategic decision-making in marketing and trade.

Businesses must embrace advanced analytics, ethical AI, and interdisciplinary collaboration to remain competitive. Strong industry-academic partnerships can foster innovation, shape curricula, drive market research, and develop data-informed strategies, especially in global and agricultural markets. Algorithms and analytics drive competitive advantage in global marketing and trade, supporting agricultural or food marketing, feeding into both local and global marketing channels. Analytics enhance these channels by refining strategies, while feedback from local markets informs further optimization. This data-driven cycle strengthens decision-making and global reach. In particular, African farmers and food marketers can harness the power of algorithms and data analytics to gain real-time market insights, predict demand trends, and improve production efficiency. By leveraging these tools, farmers can access broader markets, reduce post-harvest losses, streamline supply chains, and make data-driven decisions. This approach empowers both smallholder and commercial farmers to compete effectively in the global economy and respond proactively to shifting consumer preferences and trade dynamics.

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ID: 726

Application of Different Phytosolutions on Germination and Growth Indices of Wheat

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Abstract

Wheat (*Triticum aestivum* L.) is an important cereal grown in temperate and subtropical regions, mainly for food and animal feed. In Dera Ismail Khan, wheat planting is often delayed because sugarcane and cotton are prioritized. Late planting leads to poor wheat germination due to low temperatures or the presence of weeds, which can harm the crop. This issue is common across the country, affecting farming and causing wheat yields to stagnate. Increasing wheat production is a challenge. Recently, methods like seed treatment and synthetic plant growth regulators have gained popularity for boosting crop growth and ensuring wheat sprouts quickly. Allelopathy is another innovative approach that has gained attraction to mitigate biotic and abiotic stresses. The shift towards sustainable crop production is also supported by innovation in organic farming. The fallen leaves and stubble of some trees and weeds may influence emergence of wheat in the field. A study was performed at the Postgraduate laboratory, Department of Agronomy, Faculty of Agriculture, Gomal University, Dera Ismail Khan during the year 2024. Nine treatments were arranged in a completely randomized design including T1 (Control), T2 (Bitter apple), T3 (Lasoda), T4 (Parthenium), T5 (Garlic), T6 (Peelu), T7 (Conocarpus), T8 (Moringa), T9 (Algal water solution) and were compared for emergence and growth indices of wheat. Germination parameters i.e. day wise germination, germination count, germination (%), germination energy and growth indices i.e. coleoptile, root, shoot, plant length, root, shoot, whole plant fresh and dry biomass at 15 days interval were observed and found significant at 5% probability level. Leaf area, chlorophyll content, crop growth rate, net assimilation rate and photosynthetic efficiency were also noted and significantly different from control. Our results classified Moringa, Bitter apple and Algal solution as growth stimulator, while Parthenium, Conocarpus and Garlic proved as inhibitor because they hampered the wheat germination and growth indices. Moringa water solution at 10% is most effective and should be used to enhance the wheat germination and development of seedling especially in late sown wheat. Plantation of Conocarpus around the crop area should be avoided. Parthenium reduced germination and its indices, so it should be managed before wheat crop plantation.

Keywords: *Wheat germination, Seed priming, Synthetic plant growth regulators, Allelopathy, Growth inhibitors, Sustainable crop production*

ID: 727

Molecular characterization of brackish and marine water fishes of Sundarbans through DNA barcodes

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Abstract

The present study aims to apply a DNA barcoding tool through amplifying the mitochondrial candidate genes like COI for accurate identification of fish of Sundarbans mangrove wetland, to build a reference library of fish of the unique ecosystems. A total of 83 mitochondrial COI barcode sequences gene were obtained from 26 species of 26 genera, 23 families, 8 orders and one class; among the 26 species, 3 fishes were new records in Sundarbans ecosystem. The collected samples were first identified by examining morphometric characteristics and then assessed by DNA barcoding. The COI sequences of fishes were clearly discriminated among genera in their phylogenies. The average Kimura two-parameter (K2P) distances of COI barcode sequences within all fish species were 0.37 ± 0.01%. The base composition analysis for the COI sequence showed that the average percent T content was the highest and the average percent G content was the lowest; the AT content (53.60%) was higher than the GC content (46.40%). The GC contents at the first, second, and third codon positions for all fishes were 46.3%, 47.2%, and 45.7%, respectively. At the first codon position, the usage of C (18.7%) was the lowest, and the usages of the other bases were 23.00%, 27.10%, and 31.30% for T, A, and G, respectively. There were 36 haplotypes comprised this network. Each node of the network represents one unique haplotype and the bar across branches indicates the number of mutations separating two haplotypes. The overall haplotype diversity (Hd) was 0.979. The highest haplotype diversity was found 0.968 in perciformes fishes and the lowest haplotype diversity was found to be 0.000 in beloniformes, Synbranchiformes, Pleuronectiformes, Cichliformes and mugiliformes fishes. The overall nucleotide diversity (Pi) for all groups fishes were 0.37032. The nucleotide diversity was found to be highest (0.3961) in perciformes and lowest (0.000) in beloniformes, synbranchiformes, pleuronectiformes, cichliformes and mugiliformes samples. The present study describes the development of a molecular and morphometric cross-referenced inventory and assess the genetic variability of fishes of the Sundarbans. This inventory will be useful in future biodiversity studies and in forming future conservation plan. High efficiency and fidelity in species identification and discrimination were demonstrated in the present study by DNA barcoding, and we can be added that COI sequencing can be used as an authentic identification marker for Bangladesh brackish and marine fish species.

ID: 728

Evaluating Biometric Indices and Life-History Traits of Climbing Perch, *Anabas testudineus* of Baluhor Oxbow Lake in Southwestern Bangladesh: Implication for Sound Management

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Abstract

In Bangladesh, the freshwater climbing perch, *Anabas testudineus*, is a food fish with significant economical and nutritional value. To create long-term management and conservation strategies for this species, it is essential to investigate the life-history characteristics of *A. testudineus*. The present research provides the comprehensive explanation of the life-history traits (LHT), containing length-frequency distribution (LFD), length-weight and length-length relationships (LWR and LLR), form factor ($a_{3.0}$), condition factors, length at first sexual maturity (L_m), natural mortality (M_w), maximum life span (t_{max}), optimum age, where fish reaches its maximum biomass and optimum catchable length (L_{opt}) of *A. testudineus* from the Baluhor Oxbow Lake in Southwestern Bangladesh. Fish samples (n=102) were collected from May to July 2024, using various types of traditional fishing gears. Digital slide calipers and an electronic balance with an accuracy of 0.01 cm and 0.01 g, respectively, were used to measure total length (TL) and whole-body weight (BW). During this investigation, 102 specimens with measurements ranging from 6.96-13.49 cm TL and 9.59-35.07 g BW were examined. The calculated b values of *A. testudineus* showed a trend of negative allometric growth ($b<3.0$). The LWRs were highly significant ($p<0.001$) with r^2 values >0.8117. Among the four categories of condition factors in the Baluhor Oxbow Lake, K_F represented the best for well-being of *A. testudineus*. Significant dissimilarity from 100 was found in a Wilcoxon sign-ranked test for WR, indicating that habitat is uneven of *A. testudineus*. The determined $a_{3.0}$ was 0.00861, and L_m was calculated as 8.2383 (~8.30) cm TL in the Baluhor Oxbow Lake. The M_w of *A. testudineus* was 1.26 $year^{-1}$, optimum age of maximum biomass was 2.60 years and maximum life span, t_{max} was 9.65 years according in this study. The outcomes sought to help Southwestern Bangladesh and its surrounding environments in effective management of *A. testudineus* species sustainably.

Key words: *Biometry, Life-history traits, Anabas testudineus, Oxbow Lake, Bangladesh*

ID: 729

Beyond Waste: Integrative Biotechnological Pathways for Sustainable Recycling and Valorization of Industrial and Domestic Residues

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Abstract

Waste accumulation from industries and households poses the greatest challenge to environmental sustainability and public health in industrializing and urbanizing nations. Conventional technologies for treating waste, including landfill and incineration, are increasingly coming under attack for their environmental disadvantages and poor resource recovery capacities. In this context, biotechnology offers itself as a paradigm-breaking technology for valorization of waste to value-added products. In this mini-review, advanced biotechnological interventions—ranging from microbial digestion and enzymatic depolymerization to anaerobic fermentation and bio-electrochemical systems—are presented for recycling and valorization of heterogeneous waste streams. Emphasis is on engineering microbial consortia, synthetic biology for designing engineered enzymatic activity, and interfacing of bioprocesses with digital monitoring systems. Examples of case studies are microbacteria degrading plastics, upgradation of lignocellulosic biomass, biofuel, bioplastic, and organic fertilizer manufacturing. Reviewing also includes socio-economic and policy frameworks required for the adoption of bio-based circular economies, especially in low- and middle-income countries. Biotechnology offers relief to the environment as well as employment generation and propelling green innovation with furthering cross-disciplinary approaches and bridging the waste-resource gap.

Keywords: *Biowaste valorization, Microbial recycling, Industrial biotechnology, Circular economy, Waste-to-resource, Sustainable waste management*

ID: 730

Resistant Microbial Consortia in Contaminated Communities: Ecological Processes, Genomic Insights, and Biotechnological Prospects

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Abstract

Microbial populations play a fundamental role in nutrient cycling and maintaining ecosystem resilience in environments with pollutants of anthropogenic origin. Through this mini-review, the adaptable capacity, ecological processes, biotechnological perspectives, and genomic insights of microbial consortia present in contaminated freshwater and terrestrial systems are investigated. Recent advances in metagenomics, transcriptomics, and microbial ecology have provided valuable insights into microbial survival strategies under chemical stress, such as horizontal gene transfer, quorum sensing, and biofilm formation. The review categorizes microbes based on their degradative potential (e.g., hydrocarbonoclastic, heavy metal-reducing, xenobiotic-tolerant) and elaborates on how these characteristics can be utilized for soil remediation, water purification, and atmospheric detoxification. Special focus is given to the functional interaction between native microbiota and supplemented bioengineered strains for enhanced bioremediation efficiency. Ecological restoration, climate change mitigation, and environmental policy design consequences are also discussed. Lastly, understanding microbial ecosystem resilience and utility provides a promising avenue towards sustainable environmental management.

Keywords: *Microbial ecology, Environmental resilience, Bioremediation, Contaminated habitats, Metagenomics, Microbial biotechnology*

ID: 732

Decarbonizing Development: Integrated Renewable Energy Models for Climate-Smart Transitions in Emerging Economies

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Abstract

Achievement of global sustainability goals requires an immediate transition from fossil fuel-based energy systems to integrated renewable energy systems. This mini-review addresses the design principles, design considerations, and implementation strategies for integrated renewable energy systems—solar, wind, biomass, and small-scale hydropower—in the context of the emerging economies. It emphasizes how decentralised models, energy storage technologies, and hybrid grids can eradicate energy poverty and reduce greenhouse gas emissions. Key technological synergies are explored, such as solar-bioenergy coupling, optimization of the energy-water nexus, and AI applications to grid management. The review considers socio-economic factors such as financing models, gendered access to energy, and local capacity development. Policy settings and global cooperation are considered as the driving forces for sustainable transitions. Through the integration of renewable technologies that are appropriate to local resources and needs, new economies can promote simultaneously economic growth, energy security, and environmental integrity.

Keywords: *Integrated renewables, Energy transition, Decentralized systems, Climate-smart development, Sustainable energy policy, Emerging economies*

ID: 733

Climate change impact and relevance of Regenerative Agriculture to sustained crop yield, reduced pesticide load, sustained farmers livelihood and carbon mitigation

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Abstract

Climate change poses severe challenges to global agriculture, disrupting crop productivity, increasing chemical dependency, and threatening the livelihoods of small and marginal farmers. This paper examines the impact of climate change on agricultural systems and the potential of regenerative agriculture to sustain crop yields, reduce pesticide loads, support farmers' livelihoods, and mitigate carbon emissions. By integrating the Clean Food Net Zero (CFNZ) Program with Inhana Rational Farming (IRF) Technology and utilizing advanced composting methods such as Novcom Composting, the study demonstrates that regenerative practices can enhance soil health, boost crop productivity by up to 22%, and significantly reduce greenhouse gas emissions through improved nutrient cycling and carbon sequestration. Field evaluations from West Bengal, India, underscore how these interventions not only lower emissions from conventional practices but also transform agriculture into a viable carbon sink while promoting safe, pesticide-free produce. Overall, the findings reinforce that adopting a net zero regenerative agriculture model is a viable strategy for addressing the multifaceted impacts of climate change, ensuring food security, and elevating the socio-economic conditions of farming communities.

Key words : *Novcom composting technology, IRF Technology, ACFA version 2.0, Agri-Net Zero model*

Introduction

Climate change poses multifaceted challenges to modern agriculture, severely impacting crop productivity through altered weather patterns, increased frequency of extreme events, and shifts in pest and disease dynamics (Subedi et al, 2023). These climate-induced stresses not only lead to reduced crop yields but also escalate production costs, thereby exacerbating the difficulties associated with ensuring food and nutritional security (Tchonkouang et al, 2024). Moreover, the agricultural sector occupies a paradoxical role in the climate nexus—it both contributes to greenhouse gas emissions and suffers from the adverse effects of climate change (Gupta and Pathak, 2016). In countries like India, where more than 80% of the farming community comprises small and marginal farmers who are resource-poor and highly vulnerable to climatic shocks, the stakes are even higher (Mubashir and Bhat, 2021). These groups often face compounded risks, including financial instability and limited access to resilient technologies, making them disproportionately affected by the escalating costs and productivity losses due to climate variability.

Against this backdrop, regenerative agriculture has emerged as a promising paradigm aimed at sustaining crop yields while simultaneously reducing reliance on chemical inputs such as pesticides. This approach underscores the importance of managing both soil and plant health to not only restore the ecological balance but also enhance the resilience of agricultural systems. By aligning farming practices with ecosystem services, regenerative methods aim to improve soil fertility, bolster biodiversity, and enhance carbon sequestration, all while being socially acceptable, easily adoptable, economically viable, and replicable on a large scale. The integration of regenerative agriculture practices represents a critical pathway for mitigating the twin challenges of climate change and the systemic vulnerabilities of conventional agricultural systems (Lal, 2020). Its holistic framework offers a sustainable solution that addresses the immediate needs of crop productivity and farmer livelihoods, while also contributing to long-term environmental stability and climate mitigation efforts (Chepngeno et al, 2024).

In this context, Nadia Krishi Vigyan Kendra, BCKV, ICAR, located in West Bengal, India, has joined hand with Inhana Organic Research Foundation (IORF), India, to initiate a pesticide-free, safe, and sustainable cultivation system. This collaborative effort infuses the principles of regenerative farming by implementing the Inhana Rational Farming (IRF) Technology—a nature-harnessed, sustainable package that advocates for the integrated management of soil and plant health as critical components for enhancing crop sustainability, economic viability, and carbon mitigation. The initiative aims to establish a comprehensive agricultural production system that not only bolsters crop productivity and nutrient uptake efficiency but also significantly reduces pesticide loads, facilitates energy transitions, uplifts soil quality, and mitigates carbon emissions. Ultimately, the present study seeks to develop and validate a regenerative agriculture model that promotes livelihood sustenance and contributes

to broader environmental benefits including carbon mitigation, thereby uplifting the overall socio-economic conditions of the farming community.

Materials and method

Study area

The study was done at the project site comprised five villages namely Satyapole, Bhabanipur, Panchkahaniya, Dhopagachi and Bansbona in the Haringhata block of Nadia district of West Bengal, India. The area belongs to hot, moist subhumid ecological sub region (15.1) (Sehgal, 1992). The climate of the study area is characterized by oppressively hot summer, high humidity and high rainfall during the monsoon.

Concept of Clean Food Net Zero (CFNZ) program

The Clean Food Net Zero (CFNZ) Program is a transformative and holistic initiative designed to revolutionize agricultural practices while significantly reducing greenhouse gas emissions. Central to its approach is the implementation of Inhana Rational Farming (IRF) Technology—a nature-harnessed, sustainable package that integrates comprehensive soil and plant health management (Bera et al, 2023). By doing so, IRF Technology enhances crop sustainability, increases yields through improved photosynthetic efficiency, and provides a robust mechanism for carbon sequestration and emission mitigation. One of the program's core principles is that its strategies must be aligned with ecosystem services, economically viable, socially acceptable, easily adoptable, and scalable on a large scale. In addition to driving environmental benefits, the CFNZ Program is committed to ensuring that safe, nutritious, and affordable food is available for all. Equally important, it seeks to sustain and uplift the livelihoods of small and marginal resource-poor farmers by providing them with cost-effective, sustainable farming practices that can be readily implemented. Together, these integrated objectives not only fortify food security and public health but also empower farming communities, thereby contributing significantly to both climate resilience and inclusive economic development.

Novcom composting technology

Novcom Composting Technology is an advanced bio-conversion process engineered to rapidly transform diverse biodegradable wastes—including agricultural byproducts and landfill residues—into nutrient-dense compost that is exceptionally rich in microorganisms (on the order of 10^{16} cfu per gram of moist compost). This technology distinguishes itself by achieving complete compost maturity in just 21 days, a notable improvement over conventional windrow methods, primarily due to its capacity to generate a substantially higher native microbial population within the compost heap. The accelerated microbial activity not only expedites the decomposition process but also enhances soil nutrient cycling and promotes vigorous plant growth (Seal et al, 2012). Moreover, the process meets five critical criteria—safety, speed, effectiveness, comprehensiveness, and economic viability—making it highly suitable for any biodegradation program. By optimizing these biological processes, Novcom Composting Technology significantly reduces greenhouse gas emissions, particularly methane, thereby mitigating the overall carbon footprint associated with organic waste management. This efficient, cost-effective, and environmentally friendly approach renders it a valuable tool in sustainable agriculture and climate change mitigation strategies (Bera et al, 2024).

Inhana Rational Farming (IRF) Technology

Inhana Rational Farming (IRF)T Technology is a comprehensive, nature-harnessed approach to agriculture that integrates advanced soil and plant health management practices to transform conventional, chemical-intensive farming into a more sustainable, resilient, and climate-friendly system (Seal et al, 2017a). By leveraging the synergistic interactions of native soil microbes, nutrient cycling, and plant physiological processes, IRF Technology enhances nutrient uptake and photosynthetic efficiency, thereby improving crop yield and quality. Its holistic methodology not only bolsters economic viability and crop sustainability but also promotes carbon sequestration and reduces greenhouse gas emissions by lowering dependency on artificial inputs. Designed to be economically viable, socially acceptable, and easily scalable, IRF Technology offers an adaptable pathway for small and marginal resource-poor farmers, ultimately contributing to a safer food supply and more resilient agricultural ecosystems (Seal et al, 2017b).

Analytical methodology for soil, compost, crop production, energetics and carbon footprint

Analytical measurements were performed across several components—compost, soil, crop productivity, energetics, and carbon footprint—to assess the impacts of the intervention. For compost quality, 20 samples from individual Novcom compost heaps made from different biodegradable waste viz agricultural farm waste, water hyacinth, poultry litter, vegetable market waste and cow dung were collected and analyzed for various parameters following the standard methodology of Seal et al. (2012), and a Compost Quality Index (CQI) was computed as described by Bera et al. (2013). Soil quality was assessed by collecting samples from the 0–30 cm depth both before the experiment and one year later; these were analyzed for physicochemical properties and fertility using conventional methods (Jackson, 1973), while microbial biomass carbon was estimated through the dichromate oxidation method (Vance et al., 1987) and soil respiration was quantified by chemically titrating trapped CO_2 and measuring fluorescein diacetate hydrolysis (Haney et al., 2008). Crop productivity was determined according to guidelines by Patrick (1999) and converted into coconut equivalent yield, leading to an estimation of total system

productivity as per the methods of Ghosh et al. (2021) and Naveen Kumar et al. (2017). Energetic parameters—including energy use efficiency, energy productivity, specific energy, energy intensiveness, and net energy—were calculated following Banaeian et al. (2011). Finally, the carbon footprint was evaluated using the ACFA (version 1.0) carbon computing standard, developed by the Inhana Organization Research Foundation (IORF), ICAR-ATARI, Kolkata (Zone-V), and i-NoCarbon Limited (i-NC), UK, which integrates relevant IPCC guidelines with empirical research findings.

Result and discussion

Analysis of Compost quality

Novcom compost quality was evaluated across diverse substrates—including agri-farm waste, water hyacinth, banana stump, and poultry litter—revealing distinct physical, chemical, and biological properties. Moisture contents ranged from approximately 59% to 64%, while pH values remained near neutral (7.24–7.8), ensuring a favorable medium for microbial activity. Electrical conductivity was highest in the poultry litter compost (2.84 dS/m), indicating a greater concentration of soluble salts. Organic carbon percentages were notably high in the banana stump (28.2%) and water hyacinth (27.1%) composts, and the C/N ratios varied from 11.6:1 to 15.2:1, reflecting moderate maturity and balanced nutrient availability. Although total nitrogen levels were relatively consistent (1.79–2.09%), total phosphorus and potassium contents varied, with poultry litter compost exhibiting the highest phosphorus (1.24%) and banana stump the highest potassium (1.51%). Microbial assessments showed bacterial counts ranging from 23 × 10^16 to 40 × 10^16, with substrate-specific variations also observed in fungal and actinomycete populations, suggesting differences in decomposition dynamics. The CO_2 evolution rate, an indicator of microbial metabolic activity and compost stability, was markedly higher in poultry litter compost (4.61 mg CO_2–C/g OM/day) compared to the 2.13–2.39 mg CO_2–C/g OM/day observed in the other substrates. Bioassay results further demonstrated that composts derived from agri-farm waste, water hyacinth, and banana stump supported robust plant growth, as evidenced by seedling emergence rates between 107–113% and germination indices exceeding unity (1.09–1.12), while the poultry litter compost showed slightly diminished performance (93% seedling emergence and a germination index of 0.89), indicating minor phytotoxicity. Overall, these findings illustrate that Novcom composts, particularly those made from agri-farm waste, water hyacinth, and banana stump, possess favorable qualities for sustainable agricultural application, balancing nutrient enrichment with microbial vitality and minimal phytotoxic risk**.**

Table 1 : Analysis of Novcom compost quality

Sl No	Quality parameters	On-Farm Novcom Compost			Poultry litter
		Agri-farm waste	Water hyacinth	Banana stump	
1	Moisture (%)	61.2	64.3	63.7	59/1
2	$pH_{(water)}$	7.61	7.24	7.41	7.8
3	EC (1 :5) dS/m	1.91	2.64	1.93	2.84
4	Organic carbon (%)	22.2	27.1	28.2	23.1
5	CMI[2]	2.17	1.83	1.91	2.37
6	Total nitrogen (%)	1.91	2.09	1.79	1.89
7	Total phosphorus (%)	0.57	0.97	0.91	1.24
8	Total potassium (%)	1.04	1.11	1.51	1.17
9	C/N ratio	11.6:1	13.0: 1	15.2:1	12.2:1
10	Total bacterial count[3]	31 x 10^{16}	40 x 10^{16}	33 x 10^{16}	23 x 10^{16}
11	Total fungal count[3]	17x 10^{16}	30x 10^{14}	30 x 10^{14}	12 x 10^{14}
12	Total actinomycetes[3] count	12 x 10^{16}	17 x 10^{14}	21 x 10^{14}	9 x 10^{14}
13	CO_2 evolution rate (mgCO_2–C/g OM/day)	2.39	2.16	2.13	4.61
14	Seedling emergence (% of control)	108	113	107	93
15	Root elongation (% of control)	101	98	105	96
16	Germination index (phytotoxicity bioassay)	1.09	1.11	1.12	0.89

Crop productivity under conventional farmers practice and CFNZ program

In a comprehensive evaluation conducted over a cropping year, five major crop sequences were studied: CS 1 (Tomato–Cucumber–Coriander), CS 2 (Potato–Brinjal–Cauliflower), CS 3 (Potato–Okra–Cabbage), CS 4 (Brinjal–French bean–Spinach), and CS 5 (Pumpkin–Okra–Cabbage). Notably, the Potato–Brinjal–Cauliflower sequence (CS 2) demonstrated the highest productivity, yielding 52,125 kg/ha under conventional farmer practices (CFP) and increasing to 92,775 kg/ha under the Clean Food Net Zero (CFNZ) program. This was followed by the Potato–Okra–Cabbage sequence (CS 3), which achieved yields of 66,937.5 kg/ha under CFP and 82,125 kg/ha

under CFNZ. On average, the CFNZ program led to a 22% increase in crop yields compared to conventional practices. The observed yield improvements are scientifically attributed to the adoption of enhanced soil and plant health management practices, particularly through the integration of Inhana Rational Farming (IRF) Technology. This technology promotes a synergistic soil–plant interaction by boosting microbial biomass, nutrient cycling, and overall resource use efficiency, thereby enhancing photosynthetic activity and crop growth. Moreover, the methodological framework of the CFNZ program adheres to critical criteria—being aligned with ecosystem services, economically viable, socially acceptable, and readily scalable—which further supports its potential to deliver sustained productivity improvements while mitigating environmental impacts.

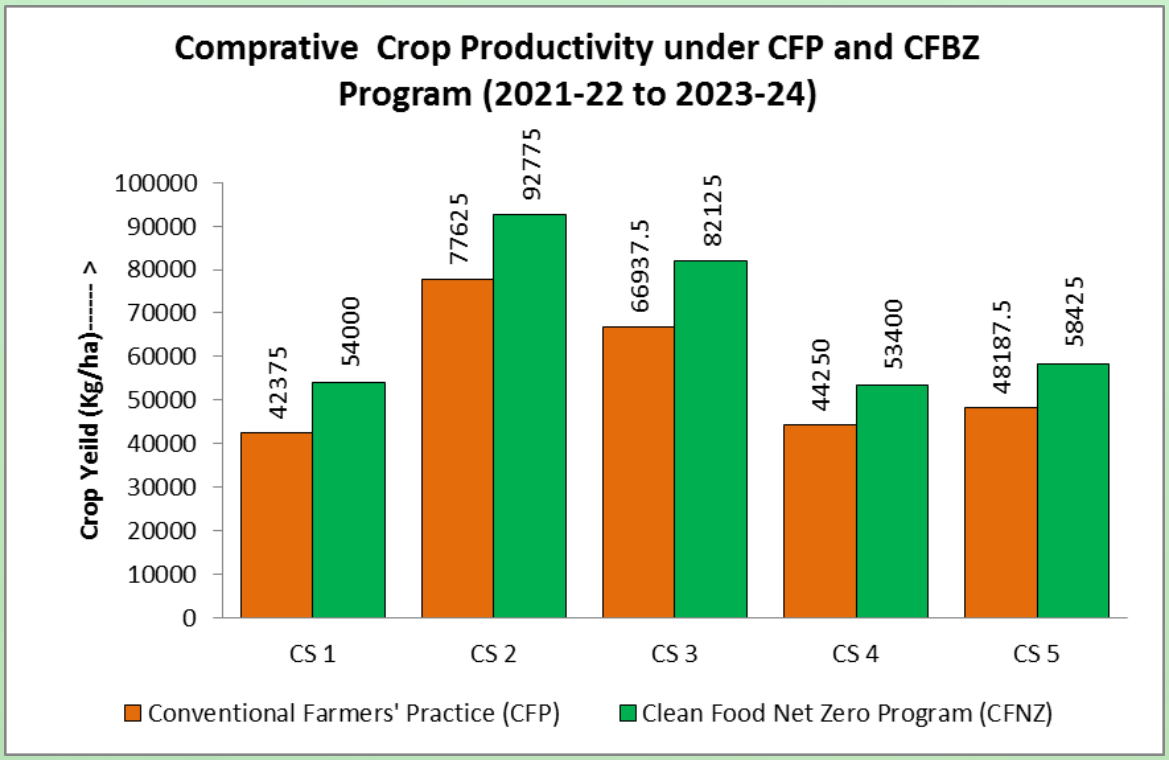


Fig 1 : Comparative evaluation of crop productivity under CFP and CFBZ program

The Status of Food Safety in India and how 'Clean Food' Safety correlates

In India, food safety is regulated by the Food Safety and Standards Authority of India (FSSAI) under standards aligned with the Codex Alimentarius Commission, setting a conventional maximum pesticide residue limit of 0.1 ppm in vegetables. However, for organic produce and the 'Clean Food' initiative, the limit is tightened to 0.01 ppm—not per individual pesticide, but as a cumulative ceiling irrespective of the number of pesticide groups present. From 2008 to 2018, analysis of 181,656 food samples revealed that 3,844 samples (2.1%) surpassed the prescribed limits. A focused study on 584 vegetable samples detected residues above 0.1 ppm in 83 samples (14.21%), with data showing that 34.93% of vegetables from conventional markets were contaminated, compared to only 3.85% of samples collected from the 'Clean Food' project area. Risk assessment further categorized vegetables into three groups: low/no risk (e.g., peas, cabbage, cauliflower, potato, onion, yam, spinach, and coriander with contamination in less than 20% of samples), moderate risk (e.g., French bean, cucumber, carrot, tomato, pumpkin, and ridge gourd with 20–50% contamination), and high risk (e.g., pointed gourd, brinjal, chilli, and okra with contamination in over 50% of samples). For vegetables in the high-risk category, the conventional market samples exhibited a 63.3% contamination rate, whereas those from the Clean Food project area recorded only 12.7%—an approximate 80% risk reduction. Additionally, while conventional market samples showed a single pesticide group presence in 21.6% of cases, along with 7.8% and 3.2% for two and three groups respectively, the Clean Food area reported only a 3.8% occurrence of a single pesticide group. This comprehensive data highlights that the 'Clean Food' standard stands as one of the most stringent and effective measures in minimizing pesticide exposure in India's vegetable supply.

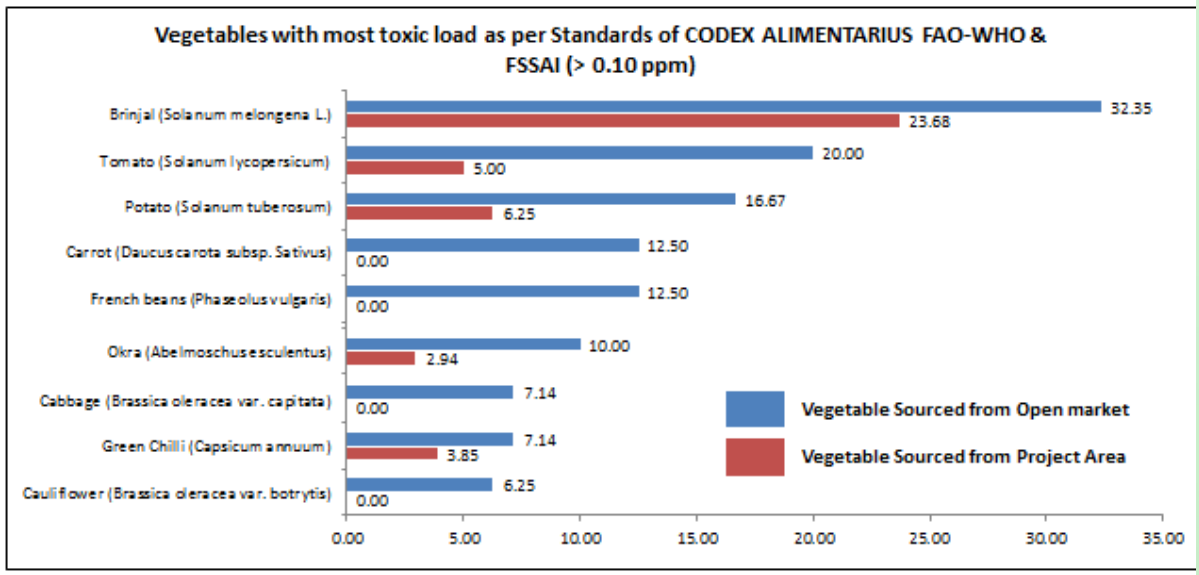


Fig 2 : Variation in percent vegetable samples having pesticide residue under conventional farmers practice and CFNZ program

Energy transition

Agriculture serves as both a consumer and producer of energy, providing bioenergy and food. The Green Revolution significantly increased energy use in agriculture due to the widespread adoption of chemical fertilizers, pesticides, and mechanization. Currently, the agri-food chain accounts for approximately 30% of global energy consumption, with a substantial portion occurring post-harvest and primarily derived from fossil fuels.This intensive energy use has led to environmental challenges, including soil and water pollution, and elevated CO_2 and N_2O emissions that contribute to global warming. Therefore, enhancing energy efficiency in agriculture is vital to minimize environmental impacts, conserve natural resources, and promote sustainable agricultural practices.

Energy analysis of agricultural ecosystems provides a concrete approach to assess energy use efficiency, identify environmental issues, and evaluate the sustainability of crop production systems. In this context, an assessment was conducted on various crop sequences under the 'Clean Food Net Zero' production model, comparing scenarios with 50% and 100% reductions in chemical nitrogen use against conventional farming practices. The study focused on five major cropping sequences prevalent in the project area: Tomato-Cucumber-Coriander, Potato-Brinjal-Cauliflower, Potato-Okra-Cabbage, Brinjal-French Bean-Spinach, and Pumpkin-Okra-Cabbage.

The energy footprint plays a crucial role in agricultural sustainability, as both direct and indirect energy inputs in farming directly impact carbon emissions, resource efficiency, and environmental resilience. High energy-intensive practices contribute to greenhouse gas emissions, accelerating climate change. Notably, about 30% of the world's energy is consumed within agri-food systems, and energy use is responsible for a significant portion of greenhouse gas emissions in this sector .

The study revealed that energy use efficiency (EUE) was notably higher under the 'Clean Food' production model, especially in the Potato-Okra-Cabbage and Potato-Brinjal-Cauliflower sequences. This finding is significant, considering that energy input was also considerably higher in these two cropping sequences. An EUE greater than 2.0, along with sustained crop productivity under 'Clean Food' production, underscores the model's potential for economic sustainability and greenhouse gas mitigation within safe and sustainable agriculture.

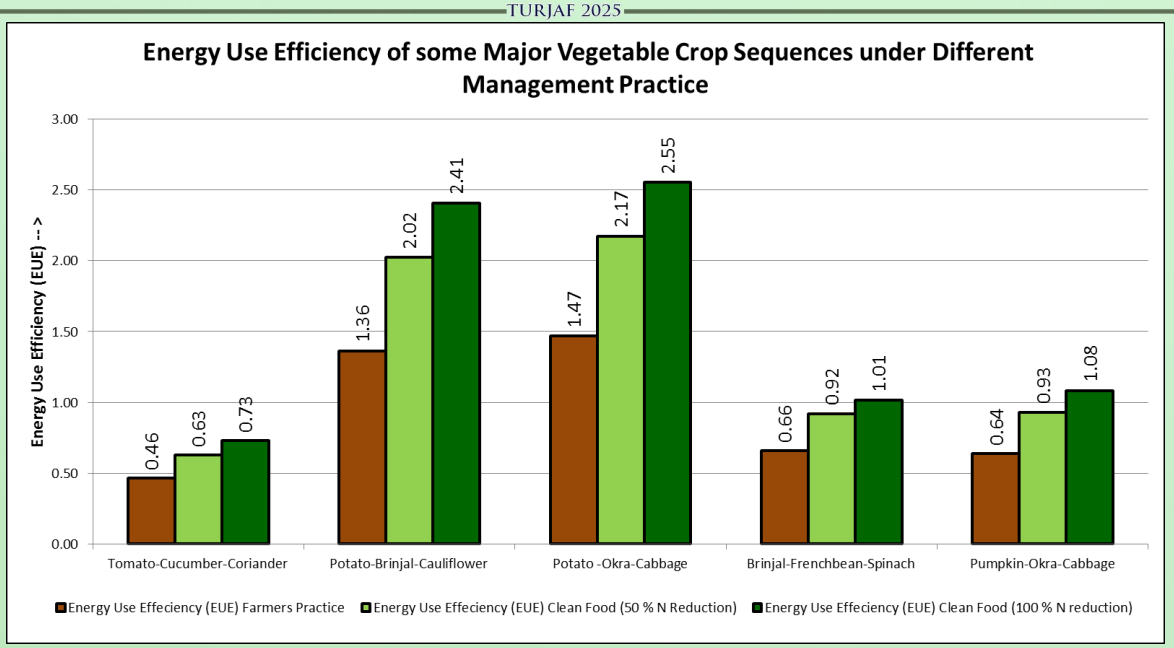


Fig 3: Comparative study of energy use efficiency under different management practice

Comparative GHG Emission and Mitigation in Conventional and Clean Food Net Zero Crop Sequences

A comparative analysis of different cropping sequences under varied management practices—Conventional Farmers' Practice (CFP) versus the Clean Food Net Zero (CFNZ) Program—reveals significant differences in GHG emission and mitigation potential. Using the Cool Farm Tool (Hillier, 2013), the study quantified the emissions in terms of kg CO_2 equivalent per hectare and per kilogram of produce. Under CFP, where chemical nitrogen fertilizers are used, the average GHG emission is positive—for instance, +0.13 kg CO_2-eq per kg produce—indicating net emissions. In contrast, the CFNZ approach, which incorporates either a 50% or 100% nitrogen reduction alongside the adoption of IRF Technology, achieves net mitigation, with average emissions of –0.05 and –0.23 kg CO_2-eq per kg produce, respectively. .

Table 2 : Agricultural Component wise GHG (kg CO_2 equv./ha/year) Footprint

Agricultural Operations (component-wise)	Farm Chemical Production Component wise	Crop GHG (kg CO_2 equv./ha/year) Footprint	CFNZ under IRF Technology	GHG (kg CO_2 equv./ha/year) Footprint
Seed, Seed Treatment & Nursery Management	Chemical Seed Treatment	8.28	IRF Seed Treatment	0.86
	Seed Bed & Nursery	3.08	Seed Bed & Nursery	1.5
	Direct Seed Sowing	12.38	Direct Seed Sowing	11.02
Transplanting		6.27		7.63
Land Preparation		373.06		376.11
Irrigation		463.82		488.48
Weed Management		5.56		5.72
Crop Nutrient Management	Chemical Nutrient Management	4934.97	Nutrient Management through Novcom Compost	(-) 15269
Crop Protectant	Chemical Crop Protection	431.29	Inhana Plant Health Mgt (IPHM)	16.86
Total GHG (kg CO2equv. /ha/year)		(+) 6238.7		(-) 14330.77

In the detailed crop sequence analysis, sequences such as Tomato-Cucumber-Coriander, Potato-Brinjal-Cauliflower, Potato-Okra-Cabbage, Brinjal-French bean-Spinach, and Pumpkin-Okra-Cabbage showed marked shifts from positive emission values under conventional practices (ranging from 4682.9 to 8254.5 kg CO_2-eq/ha) to substantial negative values under CFNZ (ranging from –13085.3 to –15275.9 kg CO_2-eq/ha). Moreover, when only chemical pesticides were completely eliminated—as captured in the Phase-II Project—the intervention yielded an additional 18–20% reduction in GHG emissions, underscoring that nitrogen fertilizers are the predominant GHG contributors under CFP. The highest emission reduction of 7100 kg CO_2-eq per ha per year was

observed in the Potato-Okra-Cabbage sequence, and in terms of per kilogram yield, the Tomato-Ridge Gourd-Spinach and Pointed Gourd–Cauliflower sequences emerged as the most carbon efficient (around 0.07 kg CO_2-eq per kg). Overall, the study demonstrates that transitioning from CFP to CFNZ—particularly with a 100% reduction in both nitrogen fertilizers and chemical pesticides—has the potential to transform agriculture from a net greenhouse gas emitter into a significant GHG sink

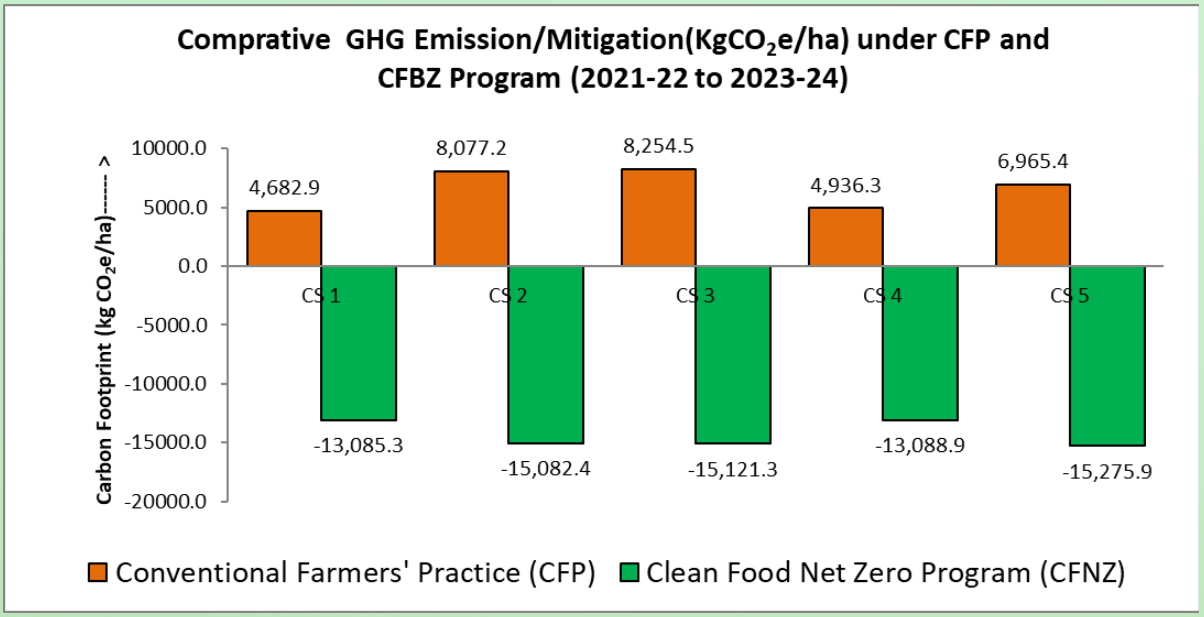


Fig 4 : Comparative assessment of Carbon footprint inder CFP and CFNZ management Program

Economics, employment generation

The impact of the Clean Food (CF) Model on employment generation and livelihood support is significant and multifaceted. A comparative study, as illustrated in Figures 16 and 17, indicates that adopting the CF Model can boost employment opportunities by up to 16.7 percent, demonstrating its potential to enhance local job markets and stimulate rural economies. In addition to creating more jobs, the CF Model also positively influences farmers' incomes. An analysis of gross income based on major cropping sequences—using a six-month average from December 2022 to May 2023 of farmers' procurement prices as reported by Sufal Bangla—revealed that even within conventional market frameworks, there is a potential income increase of up to 19.7 percent, even without implementing any value-added marketing strategies. This suggests that if a dedicated market chain were established for these pesticide-free, value-added products, the income potential for farmers could be amplified considerably. Such improvements not only underscore the CF Model's capacity to transform agricultural practices into more sustainable and profitable systems but also highlight its broader role in supporting rural livelihoods and contributing to overall economic development.

Development of net zero regenerative agriculture model for livelihood sustenance and carbon mitigation

The development of a net zero regenerative agriculture model for livelihood sustenance and carbon mitigation is a transformative approach that integrates sustainable farming practices with robust climate action measures. By merging strategies such as the Clean Food Net Zero (CFNZ) Program and Inhana Rational Farming (IRF) Technology, this model focuses on reducing reliance on chemical nitrogen fertilizers and pesticides, thereby lowering greenhouse gas emissions while enhancing soil health and crop productivity. Regenerative practices—bolstered by advanced technologies like Novcom composting—accelerate organic matter recycling, improve nutrient cycling, and promote microbial biodiversity, which in turn increases carbon sequestration and creates a net carbon sink. This holistic model not only improves yields by up to 22% and raises income potential by nearly 20% compared to conventional practices but also fortifies the socio-economic conditions of resource-poor, small, and marginal farmers. Ultimately, by aligning agricultural productivity with environmental resilience, the net zero regenerative agriculture model offers a sustainable pathway to secure both the livelihoods of farming communities and the long-term stability of the climate.

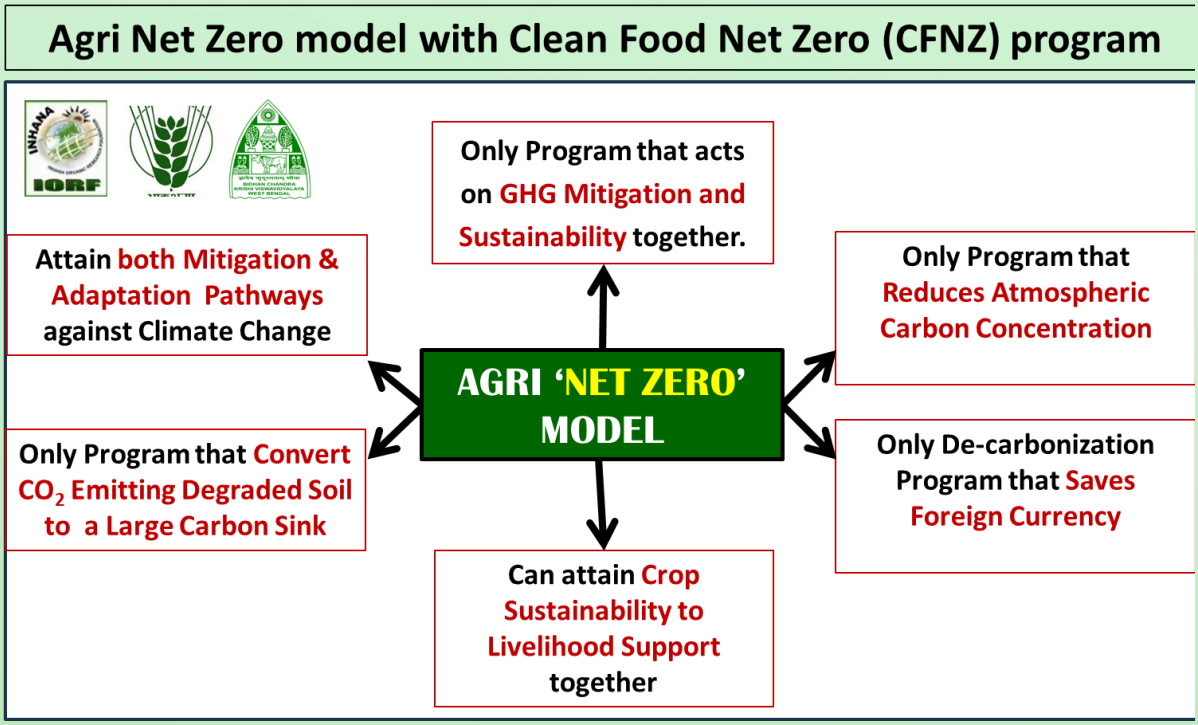


Fig 5 : Development of Agri-Net Zero model with adoption of CFNZ program

Conclusion

The comprehensive studies and analyses presented affirm that integrating a net zero regenerative agriculture model can substantially transform conventional farming practices into sustainable, climate-resilient systems. By adopting innovative practices such as the Clean Food Net Zero (CFNZ) program and Inhana Rational Farming (IRF) Technology, agriculture can transition from being a major greenhouse gas emitter to acting as a robust carbon sink. This transformation is supported by enhanced soil and plant health, exemplified by improved crop yields, nutrient cycling, and effective microbial activity as observed in advanced composting technologies like Novcom Composting. Furthermore, the integrated model not only mitigates environmental impacts—achieving marked reductions in greenhouse gas emissions—but also bolsters rural livelihoods by increasing employment opportunities and farmers' income. Ultimately, these findings underscore the viability of a regenerative agricultural framework that aligns economic sustainability with environmental stewardship, offering a replicable blueprint for addressing the twin challenges of climate change and food security on a global scale.

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Behavioral Pattern and Welfare Status of Indigenous Chicken in Rural Communities of Bangladesh

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Abstract

Poultry production constitutes a pivotal component of the rural economy in Bangladesh, with indigenous chickens representing one of the most significant poultry species. This study was conducted across five Upazilas in the Barishal district of Bangladesh to investigate the behavioral patterns and welfare status of indigenous chickens within rural communities. Indigenous chickens are still regarded as xpre sources of income, food security, and employment for rural populations. However, the welfare of these chickens often remains overlooked due to a lack of knowledge and awareness among the people.

Key behavioral aspects such as dust and sand bathing, foraging, scratching, roosting, pecking, nesting, peck order, brooding, and hen-chick relationships were meticulously documented in this study. Welfare assessments concentrated on housing, feeding, drinking, and health conditions. The findings revealed that indigenous chickens exhibit a diverse array of behavioral patterns. Notably, 84.5% of the chickens engaged in foraging, while 82.6% participated in dust and sand bathing; 79.5% demonstrated roosting and perching behavior. Among social interactions, 73.9% of male birds displayed a peck order. Brooding, observed in 81.4% of the subjects, is also a pronounced reproductive behavior among indigenous chickens. A significant majority, 78.3%, exhibited mating behavior, and the hen-chick relationship, characterized by 80.1%, reflects a critical maternal instinct.

Nonetheless, welfare challenges pose significant constraints on the ability of indigenous chickens to xpress their natural behaviors. Inadequate feeding, drinking, housing, and healthcare facilities emerged as primary welfare issues. The study underscores that the appropriate expression of behavioral patterns and welfare conditions could enhance the production performance of indigenous chickens. Disseminating knowledge regarding the proper rearing of indigenous chickens and fostering awareness among rural communities about essential welfare tools such as improved housing, balanced nutrition, and vaccination programs can significantly elevate the production performance of indigenous chickens and contribute to the development of sustainable poultry production.

Keywords: *Indigenous chicken, behavior, welfare, food security, and sustainable development*

Introduction

Bangladesh possesses a rich historical legacy of rearing indigenous chickens. In rural communities, these chickens are raised not only for livelihood and income generation but also for ensuring protein security and alleviating unemployment among youth, women, and children. Despite the socio-economic and nutritional significance of indigenous chickens, issues surrounding their behavioral patterns and welfare have not garnered adequate scientific attention in Bangladesh.

Indigenous chickens in rural settings exhibit a diverse array of behaviors, including scavenging, dust bathing, sand bathing, perching, preening, egg laying, incubation, and hatching, among others. These behaviors can be categorized as general, social, productive, and reproductive in nature. Bracke and Hopster (2006) elucidated that the natural behavior of animals refers to the actions typically exhibited by these creatures when they are situated in environments that closely resemble their native habitats. Any deviation from these innate behaviors may result in psychological distress, such as depression, in chickens. Indigenous chickens, in rural settings, often forage around household premises to fulfill their nutritional needs; however, in many instances, proprietors provide only a meager quantity of feed, consequently failing to meet the birds' nutritional requirements, which contravene the principles of animal welfare. Behavior is a pivotal component of animal well-being. Ensuring that chickens can maintain and express their natural behaviors significantly contributes to their physical and psychological health. According to the Appleby *et al*., 2004, behavior reflects an animal's health and environment, studying behavioral patterns can be a useful tool for assessing welfare.

This study examines the current state of indigenous chicken behavior and welfare in the rural regions of Bangladesh. By identifying prevalent behavioral patterns and welfare challenges, the aim of the study was to explore the behavioral patterns and welfare status of indigenous chickens in rural Bangladesh and identify critical challenges and potential areas of improvement.

Materials and Methods

Selection of the Study Area

A comprehensive survey was conducted across five uapzillas in the Barishal district, namely Barishal Sadar, Babuganj, Agaljhara, Banaripara, and Gouronodi. The households were meticulously selected based on their behavioral patterns and the welfare status of indigenous chickens within the study area.

Experimental data collection

The study was conducted across five upazilas in the Barishal district, specifically Babuganj, Barishal Sadar, Anaripara, Agaljgara, and Gouronodi, with the objective of investigating the inherent behavioral patterns and welfare assessments of indigenous chickens. A total of 160 households were surveyed, comprising 32 households from each upazila, to facilitate the research. Data were meticulously collected through face-to-face interviews and direct observations.

Statistical Data Analysis

The quantitative and qualitative data was analyzed statistical analysis IBM SPSS version 20.0. Data were analyzed through descriptive statistics. The results were expressed in frequencies, mean, percentage and p value.

Behavioral Parameter

Following behavioral parameters were observed in the study area-

1. General behavioral pattern
a. Feeding
b. Drinking
c. Dust and sand bathing
d. Scratching
e. Foraging
f. Roosting/Perching
g. Pecking

2. Social behavior
a. Peek order
3. Productive and reproductive behavioral pattern
a. Mating
b. Nesting
c. Brooding
d. Hen-Chick- Relationship

Welfare Assessment Framework

Welfare assessment was based on the five freedoms framework (FAO, 2010)

1. Freedom from hunger and thirst
2. Freedom from discomfort
3. Freedom from pain, injury, or disease
4. Freedom to express normal behavior
5. Freedom from fear and distress



(a) (b) (c) (d) (e) (f)

Figure : (a) Poultry house, (b) Day basket, (c), Alert and active, (d) Scavenging feeding, (e) Dust bathing; and (f) Hen -chick -relationship

Results and Discussions

General behavior pattern of indigenous chickens

Behavior and welfare criteria of indigenous chickens primarily encompass general behavior, social interactions, and both productive and reproductive conduct, among other aspects. This study delves into various dimensions of behavioral patterns and welfare concerns pertaining to indigenous chickens within rural communities in Bangladesh.

Feeding

Table 1 showed a significant majority (89.39%) of the farmers in the study area reared indigenous chickens utilizing free-range scavenging systems. They provide a minimal quantity of feed to the birds, which is inadequate for their nutritional needs. Consequently, hunger is prevalent among the chickens, which contravenes the principles of animal welfare.

Drinking

Respondents in the study area (62.5%) provided no potable water for the birds; consequently, the avian resorted to consuming contaminated water from their surroundings or the effluent of tube wells (Table 1). As a result, dehydration is prevalent among indigenous chickens, which contravenes the principles of avian welfare.

Dust and sand bathing

Table 1 showed that 82.6% of flock observed dust bathing in the study area, especially during warmer period of the day which is significant.

Table 1: General Behavioral Pattern of Indigenous Chickens

Variables	Babuganj	Barishal Sadar	Banaripara	Gouronodi	Agaljara	Grand Mean	P Value
Feeding							
Scavenging	18.12	17.5	18.12	18.12	17.5	89.39	0.000*
Supplementation	1.875	2.5	1.875	1.875	2.5	10.63	
Drinking							
Yes	3.75	7.5	10.625	9.375	6.25	37.50	0.013*
No	16.25	12.5	9.375	10.625	13.75	62.50	
Dust and sand bathing							
Yes	16.875	15.625	17.5	17.5	15	82.5	0.000*
No	3.125	4.375	2.5	2.5	5	15.5	
Scratching							
Yes	16.875	15.625	15.625	16.875	15	80	0.000*
No	3.125	4.375	4.375	3.125	5	20	
Foraging							
Yes	18.75	17.5	16.875	17.5	13.75	84.4	0.028*
No	1.25	2.5	3.125	2.5	6.25	15.6	
Roosting or perching							
Yes	16.87	15.625	17.5	15	14.375	79.37	0.114
No	3.125	4.375	2.5	5	5.625	20.63	
Peeking							
Yes	16.875	15.625	18.75	17.5	16.875	85.63	0.000*
No	3.125	4.375	1.25	2.5	3.125	14.37	

*=Significant ($p<0.05$)

Scratching

Scratching (80.1%) is a common behavioral practice among the birds. Significance number of birds showed scratching behavior (Table 1).

Foraging

Indigenous chickens exhibit a remarkable tendency for foraging, with an impressive 84.5% of their activity occurring in the surrounding environment (Table 1). They predominantly derive their sustenance from the abundant resources available in their external habitat.

Roosting or Perching

Roosting (79.5%) represents a prevalent behavioral pattern among indigenous chickens (Table 1). This practice not only enhances the physiological well-being of the birds but also mitigates soiling of the ground and diminishes incidences of cannibalism within the flock.

Social behavior

Pecking order

One of the most sociable behaviors exhibited by chickens is the establishment of a pecking order, or dominance hierarchy (73.9%). Chickens demonstrate this social stratification among their peers in free-range environments or within a flock. This characteristic is evident within a collective of birds or within a chicken community.

Productive and reproductive behavior

Nesting

Nesting is a prominent and fruitful behavior observed in indigenous chickens, constituting 79.5% of their overall activities (**Table 3)**. These chickens engage in nesting behavior prior to oviposition. To facilitate successful egg-laying, it is imperative to provide suitable nesting environments; consequently, the maintenance of an appropriate nest box significantly enhances egg production.

Mating behavior

Mating behavior is one of the reproductive behaviors of chicks. About 78.3% of birds showed mating behavior in the study area which isn't significant.

Brooding

Brooding behavior showed just after incubation of chicks. Brooding is a maternal instinct of indigenous chicken. About 81.4% of indigenous chicken showed brooding behavior and it's not significant.

Hen chick relationship

Indigenous chicken showed strong hen chick relationship. Most of the cases hen were roaming with birds often too long and showed stung imprint among them. About 80.1% birds showed hen chick relationship which is significant.

Welfare status of Indigenous Chicken

Housing

Poultry houses in the study area were traditional houses, kept miscellaneous poultry species together. This housing facilities don't meet the welfare criteria "freedom from discomfort" and birds were consequently perdition and exposure to environmental stress was common (Rahman *et al.,* 2017).

Table 2: Social behavioral pattern of indigenous chicken

Variables	Babuganj	Barishal Sadar	Banaripara	Gouronodi	Agaljara	Grand Mean	P Value
Pecking order							
Yes	14.375	15.625	15	15	13.75	73.75	0.224
No	5.625	4.375	5	5	6.25	26.25	

*=Significant (p<0.05)

Table 3: Productive and reproductive behavioral pattern of indigenous chicken

Variables	Babuganj	Barishal Sadar	Banaripara	Gouronodi	Agaljara	Grand Mean	P Value
Mating							
Yes	16.875	15.625	17.5	14.375	13.75	78.13	0.074
No	3.125	4.375	2.5	5.625	6.25	21.87	
Nesting							
Yes	16.875	15.625	18.75	13.125	15	79.5	0.018
No	3.125	4.375	1.25	6.875	5	20.5	
Brooding							
Yes	16.875	15.625	17.5	18.75	12.5	81.25	0.008
No	3.125	4.375	2.5	1.25	7.5	18.75	
Hen-chick relationship							
Yes	18.125	15.625	13.75	18.75	13.75	80	0.007
No	1.875	4.375	6.25	1.25	6.35	20	

*=Significant (p<0.05)

Feeding and Drinking

Feeding practices in the study area predominantly consisted of scavenging (89.39%), with only 10.63% of participants providing nutritional supplementation to the birds. Consequently, the birds frequently experienced malnutrition. Access to clean drinking water was available in 37.50 % of cases, which consequently reflects the chickens' freedom from hunger and thirst (Hossen, 2010).

Bio-security and Health Status

Birds have been afflicted by various health concerns, including diseases, infections, and disorders. A mere percentage of respondents had access to veterinary services, and preventive health management practices were predominantly lacking (Rahman *et al*., 2017; FAO, 2010).

Housing

Birds have been afflicted by various health concerns, including diseases, infections, and disorders. A mere percentage of respondents had access to veterinary services, and preventive health management practices were predominantly lacking (Rahman *et al*., 2017; FAO, 2010).

Health status

No vaccination programme (68.1%) was maintained during rearing of indigenous chicken as a result highest mortality of chicks and adult birds was very common. This is also against welfare.

Conclusion

Indigenous chickens play a pivotal role in the rural communities of Bangladesh. Conducting a behavioral study of these indigenous birds is crucial, as their behaviors are indicative of their welfare status. A deficiency in behavioral expressions can signal significant welfare concerns. Inadequate housing, insufficient nutrition, and health complications pose serious threats to these birds. Conversely, the presence of adequate behavioral expressions contributes to the enhancement of their welfare. It can be concluded that a comprehensive behavioral analysis can significantly elevate the welfare standards of indigenous chickens.

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ID: 735

Agri-Pharma-Food Nexus: Harnessing Edible Plants as Bio-factories for Next-Gen Pharmaceuticals

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Abstract

The intersection of agriculture, pharmaceutical innovation, and food science is giving rise to a transformative field: the use of edible plants as platforms for pharmaceutical production, commonly referred to as molecular pharming. This review explores the current advances, opportunities, and challenges associated with utilizing genetically engineered crops—such as lettuce, rice, maize, and tomatoes—to produce therapeutic proteins, vaccines, and antibodies. Compared to traditional bioreactor-based methods, plant-based expression systems can reduce production costs by up to 60% and lower the risk of contamination by approximately 80%. Key developments in chloroplast transformation, transient expression systems, and glycoengineering have improved protein yields to levels of 1.5–3.0% of total soluble protein in edible tissues. The review highlights successful case studies, including plant-derived vaccines for hepatitis B and Norovirus, which showed immunogenic responses in 75–90% of subjects during early trials. In addition to cost-effectiveness and scalability, these edible plant platforms offer the potential for oral delivery, eliminating the need for cold-chain logistics and sterile injection, which could increase global vaccine accessibility by over 40%. Critical discussions include the regulatory landscape, biosafety, and consumer perception—particularly concerning genetically modified organisms (GMOs) in the food chain. This review emphasizes that with standardized protocols and robust safety evaluations, molecular pharming can play a pivotal role in decentralizing pharmaceutical production, particularly in low- and middle-income regions.

Keywords: Molecular pharming, plant-made pharmaceuticals, edible vaccines, agri-pharma integration, sustainable bioproduction.

ID: 737

Title: Harnessing Neglected and Underutilized Crop Species in Sub-Saharan Africa: A Pathway to Food Security and Sustainable Agriculture

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Abstract

Neglected and Underutilized Crop Species (NUCS) in Sub-Saharan Africa offer a promising avenue for enhancing food security, particularly in light of increasing climate variability and socioeconomic challenges. This review synthesizes current knowledge on the agronomic potential, nutritional benefits, and processing technologies associated with key NUCS, including fonio, teff, and amaranth (*Digitaria exilis*, *Eragrostis tef*, and *Amaranthus spp.* respectively). These crops, often overlooked in favor of major staples, demonstrate resilience to adverse environmental conditions and possess superior nutritional profiles, including high levels of essential amino acids, micronutrients, and dietary fiber. The review critically evaluates innovative food processing technologies, such as fermentation, extrusion, and milling, which can significantly improve the palatability, nutritional bioavailability, and shelf-life of NUCS. By integrating traditional processing methods with modern advancements, we propose a framework that not only enhances consumer acceptance but also promotes the commercialization of these crops. Furthermore, the review highlights case studies where successful processing techniques have revitalized local economies and contributed to sustainable agricultural practices. Key challenges facing the adoption of NUCS are addressed, including inadequate infrastructure, limited market access, and the need for supportive policy frameworks. This review advocates for a collaborative approach involving researchers, policymakers, and local communities to overcome these barriers. By prioritizing investment in NUCS research, education, and awareness initiatives, we can harness their potential to diversify diets, improve nutritional outcomes, and build resilience against food insecurity in Sub-Saharan Africa. Therefore, it is crucial to critically reassess agricultural priorities and champion Neglected and Underutilized Crop Species (NUCS) as vital cornerstones of sustainable food systems. By embracing their potential, we can significantly enrich the global dialogue on food security and agricultural sustainability.

Keywords: *Neglected and Underutilized Crop Species (NUCS); Food Security; Sustainable Agriculture; Nutritional Benefits; Processing Technologies*

ID: 738

Developing Short-Rotation Woody Biomass Feedstock in the Philippines: Strengths, Weaknesses, Opportunities, and Threats

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Abstract

Biomass energy attracts the attention of researchers, investors, developers, and policymakers because of its potential to promote local and national economies, alleviate poverty, and mitigate climate change impacts. Most biomass power plants in the Philippines derive their fuels from agricultural wastes, such as rice hulls, bagasse, coconut husks, and other agricultural wastes. However, the seasonal and limited availability of these sources are limitations for ensuring a continuous flow of raw materials supply to support an uninterrupted operation of a biomass power plant. Developing an intensive biomass feedstock farming system using short-rotation biomass crops provides opportunities for increasing productivity of marginal areas and unproductive agricultural lands, ensuring the sustainability of biomass feedstock supply for the biomass energy sector in the country, alleviating poverty, promoting rural economy, and mitigating climate change impacts. The humid tropical warm climate in the Philippines offers a favorable growing environment for year-round biomass production of some fast-growing short-rotation woody biomass crops, such as Ipil-Ipil (*Leucaena leucocephala*) and Kakawati (*Gliciridia sepium*). The country also legislated enabling laws to promote renewable energy and marketing opportunities for biomass farmers and investors. The limited science-based information concerning the sustainability of biomass energy production and the lack of scientific investigation on the potential of developing short-rotation woody biomass crops result in poor outcomes and unsustainable biomass investments. Furthermore, the long waiting period for return on investments, large investment costs during establishment, and large area requirements needed for establishing biomass plantations must be addressed to ensure the profitability, participation of biomass farmers, and interest of investors. At present, the government's voluntary commitment under the Conference of Parties (COP) 21 to reduce greenhouse emissions by 70% for the next five years and the increasing market demands for biomass provide huge opportunities for biomass investments in the country. However, these opportunities could be influenced by the changing local, national, and geopolitical political dynamics and technological advancement of other renewable energy sources, like solar, wind, nuclear, and wave, affecting demands, markets, and prices. This study contributes to understanding the feasibility and sustainability of developing a large-scale short-rotation biomass feedstock production in the country, which is a vital piece of information for informed policy and decision-making and for promoting the biomass industry in the country.

Key Words: Renewable Energy, Climate Change, Fast-growing Trees, Sustainable, Biomass Energy

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Nutritional and Health Implications of Some Essential and Non-Essential Elements in Edible Salts Commonly Consumed in Türkiye

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Abstract

Salt is a daily staple food and an important source of minerals. However, contamination in salt can pose public health risks. This study aimed to determine the concentrations of essential (calcium, potassium, magnesium, iron, manganese) and non-essential elements (aluminum, boron, chromium, nickel) in 11 commonly consumed edible salts in Türkiye and evaluate their potential health risks and nutritional contributions. The element levels were determined using Inductively Coupled Plasma Mass Spectrometry (ICP-MS), health risk assessments were conducted, and the percentage contributions of the elements to daily dietary reference values were calculated. Element levels varied significantly among samples. For instance, aluminum levels ranged from 0.13 to 5.60 mg/kg. The highest calcium, potassium, magnesium, aluminum, iron, manganese, and nickel levels were found in S5 (Himalayan salt), while chromium was highest in S9 (rock salt). Hazard index values remained below the safety threshold, and all salts were evaluated as low risk. Although the risk assessment suggests no immediate threat based on the current data, the necessity for comprehensive element analyses of edible salts remains crucial. Moreover, despite the variations in mineral levels, the assessed salts are unlikely to meet the recommended daily intake levels for essential minerals.

Key Words: *Salts; Elements; Public health; Risk assessment; Food contamination*

Introduction

Salt is an essential source of minerals required by humans and is utilized in various industries, including metallurgy, textile, medicine, agriculture, and chemicals (Horasan and Öztürk, 2021). Table salt is commonly added to enhance the flavor of foods and serves as a preservative for many canned, salted, pickled, and fresh foods (Elias et al., 2020; Nagendra et al., 2020). While salt exists in liquid form in seas, lakes, and other water sources, it is classified as rock salt in its solid form. The sea is the largest global source of salt, with its salt content influenced by geographical structures, physical and chemical changes in rocks, evaporation, and climatic conditions. In Türkiye, raw salt production occurs from seawater, underground rock mining, lake water, and underground spring water (Türkiye Mineral Research and Exploration General Directorate, 2023).

Elements can be examined in two groups, essential and non-essential when evaluating their effects on human health (Demir et al., 2020). Essential elements have important functions in the human body, but they can be toxic at high consumption rates. However, essential elements have homeostatic mechanisms that increase or decrease absorption and excretion to maintain certain levels in the body. Insufficient essential element intake results in deficiency symptoms, while high intake can be toxic to metabolisms (Somuncu et al., 2025). On the other hand, non-essential elements have no known function in the human body, they can be toxic even at low concentrations and cause health problems. Long-term exposure to non-essential elements can lead to physical (i.e. blood pressure changes, changes in blood composition, chronic pain, etc.) and psychological (i.e. anxiety, passivity, etc.) disorders, neurodegenerative diseases, and cancer (Witkowska et al., 2021; Marquès et al., 2022; Jomova et al., 2024). The severity of their health impacts depends on several factors the dose, the route and the duration of exposure, and the degree of bioaccumulation in the body (Ali et al., 2018).

Since salt is a substance consumed daily, any contamination can have adverse effects on consumer health. The natural resources from which salt is obtained may sometimes contain high levels of essential and non-essential elements. These increased levels can adversely affect human health. Furthermore, industrial waste, pesticides, and other contaminants can increase the element levels in these sources (Lugendo and Bugumba, 2021). Factors such as the equipment and energy sources used in salt production, air, and water pollution in regions near salt beds, and the processing and packaging of salt can also contribute to its essential and non-essential element content (Chan et al., 2021; Di Salvo et al., 2023).

The World Health Organization (WHO) (2024) recommends a daily salt intake of less than 5 grams. However, the average daily salt consumption in Türkiye is around 10.2 g among individuals aged 15 and older (Republic of Türkiye Ministry of Health, 2019). The consumption of high salt content foods such as pickles, olives, cheese,

fermented cereal foods like tarhana and bread, along with a preference for salty flavors, may contribute to the elevated salt consumption in Türkiye. Despite public health campaigns, the slow adoption of salt reduction initiatives in food manufacturing and daily consumption practices contributes to continued high intake (Erdem et al., 2017). Therefore, the risk of people living in Türkiye being exposed to elements from edible salts is higher.
This study aims to determine the levels of some essential (calcium, potassium, magnesium, iron, manganese) and non-essential elements (aluminum, boron, chromium, nickel) in 11 different table salt products mostly consumed in Türkiye, employing the Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) method. Additionally, the findings are evaluated in the context of public health and nutrition.

Materials and Methods

Samples

A total of eleven different types of salt were analyzed, including three Himalayan salts, three rock salts, three spring salts, and two sea salts, all commonly consumed in Türkiye. Detailed information regarding the salt types and their origins is given in Table 1.

Analysis by ICP-MS method

0.3 g of each salt was weighed and dissolved in a mixture of 10 mL of nitric acid (%2 V/V) (Merck, Darmstadt, Germany) using a microwave digestion system (Cem Corporation MARS 5 Digestion). The resulting solution was then filtered. A 1 mL aliquot of each filtrate was diluted to 10 mL with ultrapure water. All samples were subsequently placed in the autosampler unit of the ICP-MS instrument (Thermo Scientific™ iCAP™ RQ) for analysis. Calibration solutions were prepared by serial dilutions using ICP-multi element standard solution-IV (1000 mg/L) (Supelco 1.11355.0100, Merck, Darmstadt, Germany). All reagents used were of analytical grade.

Health risks assessment

Salt consumption in Türkiye is twice the levels recommended by the WHO, and considering its sources, each sample needs to be evaluated in terms of Health Risk Assessment (HRA). HRA is a systematic process used to evaluate the potential adverse health effects associated with exposure to environmental, chemical, biological, or physical hazards. This multidisciplinary approach integrates toxicological, epidemiological, and statistical methods to estimate risk levels for individuals or populations.

To assess the health risks of elements in salts, the estimated daily intake (EDI) was calculated using the following formula:

$$EDI = (M \times C)/BW$$

where M is the daily salt intake (kg/day). C is the elemental concentration (mg/kg) of salts and BW is the body weight (Antoine et al., 2017). Health risks were calculated for 3 age groups: ≥21, 16 to < 21, and 11 to < 16 years.

The reference BWs estimated by The Agency for Toxic Substances and Disease Registry (ATSDR) (2023) were used to evaluate the health risks of these age groups. These values are 80, 71.6, and 56.8 kg, respectively.
Chronic daily intake (CDI) was calculated using the formula:

$$CDI = (EDI \times EDtot)/BW$$

where EDtot is the exposure duration (years). The Target Hazard Quotient (THQ) indicates the non-carcinogenic health risk caused by exposure to the relevant element (Chebli et al., 2024).

THQ was calculated using the formula:

$$THQ = CDI/RfDo$$

where RfDo is defined as consumers' daily oral exposure estimate over a long time without experiencing harmful effects and is a specific value for the trace element being assessed. The RfDo values used for Al, B, Cr, Fe, Mn, and Ni are 1, 0.02, 1.5, 0.64, 0.14, and 0.02 mg/kg/day, respectively (Antoine et al., 2017; United States Environmental Protection Agency, 2024). If THQ is <1, non-carcinogenic health effects are not expected. However, if THQ is >1 then there is a possibility that adverse health effects could be experienced.
To evaluate the cumulative risk, the Hazard Index (HI) was calculated by summing the THQ values of each element. If the HI is <1, the risk is acceptable and considered safe for human consumption, but if the HI is >1, consumption should be regarded as a potential health concern (Chebli et al., 2024).

Statistics

Statistical analyses were conducted using the SPSS software (Version 29.0 for Windows, Chicago, Illinois). The normality of continuous variables was evaluated with the Shapiro-Wilk test. For variables with a normal distribution, means and standard deviations were reported, while median values were provided for variables that did not conform to a normal distribution.

Table 1. Information about the analyzed salts in this study

Salt Samples	Type of Salts	Origin Country (Province)
S1	Spring Salt	Türkiye (Kırıkkale)
S2	Spring Salt	Türkiye (Tunceli)
S3	Spring Salt	Türkiye (Sivas)
S4	Himalayan Salt	Pakistan
S5	Himalayan Salt	Pakistan
S6	Himalayan Salt	Pakistan
S7	Rock Salt	Türkiye (Çankırı)
S8	Rock Salt	Türkiye (Yozgat)
S9	Rock Salt	Türkiye (Kars)
S10	Sea Salt	Türkiye (İzmir)
S11	Sea Salt	Türkiye

Results and Discussion

In this study, eleven edible salts commonly consumed in Türkiye were analyzed to determine their essential (calcium, potassium, magnesium, iron, manganese) and non-essential (aluminum, boron, chromium, nickel) element contents. The results showed considerable variation in elemental concentrations among the samples, as summarized in Table 2. The levels of essential and non-essential elements varied significantly among the salts. For instance, calcium concentration ranged from 36.53 mg/kg in S11 to 2,595.26 mg/kg in S5, while iron levels ranged from 1.91 mg/kg in S4 to 39.60 mg/kg in S5.

Table 3 shows the calculated daily intake of essential and non-essential elements level based on the WHO's recommended maximum daily salt intake of 5 g/day and the average daily salt consumption in Türkiye, which is 10.2 g/day. Among the analyzed salts, S5 contributed the highest amounts to the daily intake of calcium, magnesium, potassium, aluminum, boron, iron, manganese, and nickel. Salts S9, S10, and S11 were leading contributors to chromium intake.

The average concentrations indicate that calcium is the most abundant mineral across the samples, with a mean value of 1,046.05 ± 865.2 mg/kg, while manganese is the least abundant, with an average of 0.37 ± 0.37 mg/kg. Notably, sample S5 (a Himalayan salt) contained the highest concentrations of calcium (2,595.26 mg/kg), magnesium (2,457.46 mg/kg), potassium (3,612.00 mg/kg), aluminum (5.60 mg/kg), boron (2.76 mg/kg), iron (39.6 mg/kg), manganese (1.29 mg/kg), and nickel (1.40 mg/kg). Additionally, sample S9 exhibited the highest chromium concentration at 1.07 mg/kg.

Calcium is an essential mineral critical for numerous physiological functions in the body. Sufficient calcium intake is associated with preventing various health conditions, including osteoporosis, colorectal cancer, hypertensive disorders during pregnancy, and reducing LDL cholesterol levels and blood pressure (Cornick and Belizán, 2019). According to the Dietary Guidelines for Türkiye, the tolerable upper intake level (UL) for calcium has been established at 2500 mg/day for individuals aged 19 to 50 (Republic of Turkish Ministry of Health, 2022). In this study, the calcium levels of different types of salt were as follows: Himalayan salt contained 662.26-2595.26 mg/kg, spring salt contained 823.30-1853.27 mg/kg, rock salt contained 340.38-498.24 mg/kg, and sea salt contained 36.53-427.04 mg/kg. The highest calcium level was observed in S5, a Himalayan salt (2595.26 mg/kg). This was followed by S6, another Himalayan salt (2025.00 mg/kg). The lowest calcium level was found in S11, sea salt (36.53 mg/kg). However, in another sea salt, S10, it was 427.04 mg/kg. Himalayan salts are formed through the interaction of underground minerals and sea salt over hundreds of millions of years of geological compression and exposure to high underground temperatures. These ancient geological processes enriched the salts with minerals from the surrounding rocks, resulting in higher concentrations of calcium, magnesium, and potassium (Deng et al., 2023).

A significant proportion of potassium in the body is found within muscles and the skeleton, while the remainder is distributed among the central nervous system, intestines, liver, lungs, and skin. Extracellular potassium plays a crucial role in regulating cell membrane potential, as well as in nerve and muscle activities (D'Elia, 2024). In this study, the highest potassium levels were observed in Himalayan salts (848.63-3612.00 mg/kg), whereas the lowest was found in spring salts (3.30-39.63 mg/kg).

Magnesium is the fourth most abundant cation in the body and is essential for numerous physiological processes. It contributes to blood pressure regulation, myocardial and muscle contraction, neuromuscular transmission, glycemic control, energy production, synthesis of nuclear materials, transmembrane ion transport, and bone development (Al Alawi et al., 2018). In this study, the magnesium levels ranged from 582.88-2457.46 mg/kg in Himalayan salts, 18.57-26.54 mg/kg in spring salts, 33.35-239.02 mg/kg in rock salts, and 89.49-606.22 mg/kg in sea salts.

Aluminum constitutes approximately 8.8% of the Earth's crust by mass and is abundant in many rocks. Its presence in the environment is significantly influenced by natural weathering processes and anthropogenic activities such as coal burning, mining, vehicle exhaust emissions, and waste incineration. These activities contribute extensively

to environmental aluminum levels. The adverse health effects of aluminum exposure are primarily linked to neurotoxicity (Alasfar and Isaifan, 2021). Although the precise mechanism remains unclear, elevated aluminum levels have been detected in the brain tissues of patients with Alzheimer's disease and other neurodegenerative disorders (Charlebois and Pantopoulos, 2023). Aluminum exposure has also been associated with lung fibrosis, reduced lung function, bone disorders, kidney damage, hormonal imbalances, and various cancers (Bonfiglio et al., 2023). In this study, the average aluminum concentration in the analyzed salts was 1.23 mg/kg. Himalayan salts exhibited the highest aluminum levels, between 1.03 to 5.60 mg/kg. As shown in Table 3, sample S5 contributed the most to daily aluminum intake (0.057 mg/day). This equates to a weekly aluminum intake of 0.4 mg/week from this salt. According to the European Food Safety Authority (EFSA) (2008), the tolerable weekly aluminum intake for a 70 kg individual is 70 mg/week. None of the salts analyzed in this study exceeded this threshold.

Table 2. The essential and non-essential element content of salt samples (mg/kg) in this study

Salt Samples	Ca	K	Mg	Al	B	Cr	Fe	Mn	Ni
S1	1,853.27	3.30	19.37	0.76	0.06	0.59	23.89	0.48	0.95
S2	1,852.45	6.88	18.57	0.22	0.14	0.67	11.59	0.06	1.00
S3	823.30	3963	26.54	0.23	0.85	0.55	5.26	0.11	0.46
S4	662.26	949.68	1,443.65	2.61	0.91	0.76	11.91	0.53	0.43
S5	2,595.26	3,612.00	2,457.46	5.60	2.76	0.50	39.60	1.29	1.40
S6	2,025.60	848.63	582.88	1.03	0.37	0.64	31.32	0.30	1.12
S7	498.24	51.96	33.35	0.13	0.15	0.70	6.43	0.06	0.32
S8	340.38	67.20	239.02	0.56	1.39	0.63	5.46	0.19	0.26
S9	392.17	105.78	205.75	0.89	0.90	1.07	7.99	0.13	0.29
S10	427.04	184.88	606.22	0.51	3.80	1.04	6.68	0.17	0.40
S11	36.53	65.13	89.49	1.01	0.27	1.05	2.56	0.72	0.61
Mean	1,046.05	539.55	520.21	1.23 (0.76)	1.05	0.75 (0.67)	13.88	0.37 (0.19)	0.66
(Median)		(67.20)	(205.75)	1.60	(0.85)	0.21	(799)	0.37	
SD	865.2	1,074	772.3		1.20		12.21		0.39

SD: Standard deviation. Median values are given in parentheses for non-parametric variables.

Table 3. Daily essential and non-essential elements intake (mg/day) from salt

	Ca		K		Mg		Al		B	
Salt No	**WHO**	**THNS**	**WHO**	**THNS**	**WHO**	**THNS**	**WHO**	**THNS**	**WHO**	**THNS**
S1	9.266	18.903	0.017	0.034	0.097	0.198	0.004	0.008	0.000	0.001
S2	9.262	18.895	0.034	0.070	0.093	0.189	0.001	0.002	0.001	0.001
S3	4.117	8.398	0.198	0.404	0.133	0.271	0.001	0.002	0.004	0.009
S4	3.311	6.755	4.748	9.687	7.218	14.725	0.013	0.027	0.005	0.009
S5	12.976	26.472	18.060	36.842	12.287	25.066	0.028	0.057	0.014	0.028
S6	10.128	20.661	4.243	8.656	2.914	5.945	0.005	0.011	0.002	0.004
S7	2.491	5.082	0.260	0.530	0.167	0.340	0.001	0.001	0.001	0.002
S8	1.702	3.472	0.336	0.685	1.195	2.438	0.003	0.006	0.007	0.014
S9	1.961	4.000	0.529	1079	1.029	2.099	0.005	0.009	0.005	0.009
S10	2.135	4.356	0.924	1.886	3.031	6.183	0.003	0.005	0.019	0.039
S11	0.183	0.373	0.326	0.664	0.448	0.913	0.005	0.010	0.001	0.003

	Cr		Fe		Mn		Ni	
Salt No	**WHO**	**THNS**	**WHO**	**THNS**	**WHO**	**THNS**	**WHO**	**THNS**
S1	0.003	0.006	0.120	0.244	0.002	0.005	0.005	0.010
S2	0.003	0.007	0.058	0.118	0.000	0.001	0.005	0.010
S3	0.003	0.006	0.026	0.054	0.001	0.001	0.002	0.005
S4	0.004	0.008	0.060	0.122	0.003	0.005	0.002	0.004
S5	0.003	0.005	0.198	0.404	0.006	0.013	0.007	0.014
S6	0.003	0.007	0.157	0.320	0.002	0.003	0.006	0.011
S7	0.004	0.007	0.032	0.066	0.000	0.001	0.002	0.003
S8	0.003	0.006	0.027	0.056	0.001	0.002	0.001	0.003
S9	0.005	0.011	0.040	0.082	0.001	0.001	0.002	0.003
S10	0.005	0.011	0.033	0.068	0.001	0.002	0.002	0.004
S11	0.005	0.011	0.013	0.026	0.004	0.007	0.003	0.006

WHO: World Health Organization's maximum daily salt intake recommendation (5 g), THNS: Average daily salt intake for people aged 15 and over in Türkiye (10.2 g).

Boron, which has been shown to positively affect human health in recent years, is regarded as a potentially essential element (Sosa-Baldivia et al., 2016). The average daily intake of boron through diet and drinking water is approximately 1.85 mg/day (Kuru et al., 2018; Kuru et al., 2020). The United States Committee on Medicines, Food, and Nutrition (2001) has established the tolerable upper intake level (UL) for boron at 20 mg/day for adults, while the EFSA (2023) has set this value at 10 mg/day. Consuming boron in excess of 500 mg/day can result in toxicity symptoms, including headache, abdominal pain, nausea, vomiting, diarrhea, muscle contractions, weakness, disorders of the digestive and central nervous systems, glandular dysfunction, skin lesions, and shock. In this study, boron levels in different types of salt were found as follows: 0.06-0.85 mg/kg in spring salts, 0.37-2.76 mg/kg in Himalayan salts, 0.15-1.39 mg/kg in rock salts and 0.27-3.80 mg/kg in sea salts. The sample S10 contributed the highest amount to daily boron intake (0.039 mg/day). These findings indicate that it is not possible to exceed the established UL for boron through the consumption of the salts analyzed in this study.

Chromium is a potentially toxic metal released into water and groundwater from both natural and anthropogenic sources. Exposure to chromium poses serious health risks, affecting the skin, eyes, blood, respiratory and immune systems. At the cellular level, chromium exhibits genotoxic properties that can induce oxidative stress, and DNA damage, which can contribute to tumor formation (Tumolo et al., 2020). EFSA has found no convincing evidence that chromium is an essential element. One of the significant challenges in evaluating chromium deficiency is the absence of a recognized biomarker to assess chromium nutritional status (EFSA, 2014). Consequently, neither the UL nor the adequate intake level of chromium has been established. In this study, the highest chromium concentration was found in S9 (1.07 mg/kg), a rock salt, followed by S10 and S11 (1.04 and 1.05 mg/kg), sea salts with very close concentrations.

Iron is a crucial nutrient essential for oxygen transport and cellular respiration. Iron deficiency anemia remains a significant global health challenge, particularly affecting vulnerable populations such as indigenous communities, refugees, immigrants from low- and middle-income countries, and other disadvantaged groups. However, excessive iron levels in the body can lead to adverse health outcomes, primarily due to increased oxidative stress and resultant tissue damage (Vincent and Lukaski, 2018). In another study, the iron content in Himalayan salt was determined as 0.299 ± 0.0323 mg/kg using the ICP-MS method (Ercoşkun, 2022). In the present study, the iron levels ranged from 5.26 to 23.89 mg/kg in spring salt, 11.91 to 39.60 mg/kg in Himalayan salt, 5.46 to 7.99 mg/kg in rock salt, and 2.56 to 6.68 mg/kg in sea salt. The highest iron levels were observed in S5 (39.60 mg/kg), a Himalayan salt, followed by S6 (31.32 mg/kg), another Himalayan salt. The tolerable UL for iron is 45 mg/day (Republic of Turkish Ministry of Health, 2022). Based on the findings of this study, it is not possible to exceed this UL through the consumption of the analyzed salts.

Manganese is an essential trace element involved in the synthesis and activation of various enzymes in humans, as well as the regulation of glucose and lipid metabolism. Additionally, manganese is a critical component of manganese superoxide dismutase, an enzyme primarily responsible for scavenging reactive oxygen species during mitochondrial oxidative stress. Both manganese deficiency and toxicity have been linked to adverse metabolic and neuropsychiatric effects (Li and Yang, 2018). In this study, manganese levels ranged between 0.06-0.48 mg/kg in spring salt, 0.30-1.29 mg/kg in Himalayan salt, 0.06-0.19 mg/kg in rock salt, and 0.17-0.72 mg/kg in sea salt. The highest manganese level was in S5 (1.29 mg/kg), a Himalayan salt. The tolerable upper intake level (UL) for manganese is 11 mg/day (Republic of Turkish Ministry of Health, 2022). As shown in Table 3, it is unlikely that the examined salts would lead to manganese intake exceeding this threshold.

Nickel is a transition metal widely distributed in the environment, including air, water, and soil. Human exposure to nickel occurs through dietary sources, water, and inhalation. Nickel is present in fertilizers, vehicle exhaust, cigarettes, pesticides, industrial waste, and everyday materials such as jewelry, utensils, keys, and coins. Nickel exposure has been associated with allergic contact dermatitis, systemic contact dermatitis, and Systemic Nickel Allergy Syndrome (Conti et al., 2021). Although the precise molecular mechanisms remain unclear, the nervous system is one of the primary targets for nickel toxicity (Genchi et al., 2020). Recent studies have focused on nickel's role in enzymatic functions, its beneficial effects on nitrogen utilization in plants, its mechanisms of allergy induction, and its presence in food and biological tissues (Nielsen, 2021). The UL for nickel is 1.0 mg/day as soluble salts for individuals aged ≥14 years (ATSDR, 2024). Based on Table 3, it appears that the nickel content in the examined salts would not lead to intakes exceeding this UL. In this study, the lowest nickel levels were in S8, a rock salt (0.26 mg/kg), and the highest in S5 and S6, Himalayan salts (1.40 and 1.12 mg/kg). However, these Himalayan salts may not be suitable for individuals with allergic contact dermatitis, systemic contact dermatitis, or Systemic Nickel Allergy Syndrome.

Di Salvo et al. (2023) analyzed the calcium, aluminum, iron, chromium, manganese, and nickel content of 10 commercial gourmet table salts in Southern Italy using the ICP-MS method, reporting values of 3,129.34, 4.82, 5.31, 0.56, 2.17, and 2.71 mg/kg, respectively. In comparison, the values we obtained were 1,046.05, 1.23, 13.88, 0.75, 0.37, and 0.66 mg/kg, respectively, which are generally lower than those reported by Di Salvo et al (2023). Specifically, for Himalayan pink salt, their reported concentrations of calcium, aluminum, iron, chromium, manganese, and nickel were 2,926, 4.4, 2.6, 0.9, 0.0074, and 1.3 mg/kg, respectively, whereas our study found values of between 662.26-2595.26, 1.03-5.60, 11.91-29.60, 0.50-0.76, 0.30-1.29, and 0.43-1.40 mg/kg. While

chromium levels in their study were higher, our iron and manganase concentrations were significantly greater. These discrepancies may be attributed to differences in the salt source, mineralogy, salt type, geographical origin, geological features, or industrial activities surrounding the salt sources.

Table 4 presents the EDI and CDI levels of essential and non-essential elements from salts across all analyzed age groups, showing that these values remain below the RFD thresholds. Additionally, all THQ and HI levels are below 1, indicating no significant non-carcinogenic health risks associated with salt consumption in these age groups.

A study conducted in Pakistan found that salts obtained from the Sandpit salt fields, which receive untreated wastewater via the Lyari River, exhibited THQ values that were 2 to 6 times higher than the reference values, while HI values exceeded the acceptable threshold by of 20 times in terms of heavy metal contamination (Chan et al., 2021). Given the variability in salt sources and the potential health risks associated with elements, THQ and HI levels were conducted for the samples included in this study. The results indicate that aluminum, boron, chromium, iron, manganese, and nickel were present in varying concentrations across the analyzed salt samples. Notably, Himalayan salts contained the highest levels of aluminum (up to 5.60 mg/kg), iron (up to 39.60 mg/kg), and manganese (up to 1.29 mg/kg). However, despite these concentrations, HRA calculations demonstrated that the EDI and CDI of heavy metals remained below the reference dose (RfD) values for all age groups.

Table 5 provides the percentage contribution of each salt's consumption in our study to the daily dietary reference values, calculated based on the average daily salt intake in Türkiye (10.2 mg/day). These calculations were conducted using the Dietary Guideline for Türkiye (Republic of Türkiye Ministry of Health, 2022), the Summary Report on Nutrition Reference Values for Foods of the EFSA (2017), and the Food and Nutrition Board's Dietary Reference Intakes Review Committee (2019). The highest contributions to daily intake were observed for magnesium, calcium, and iron. S5, a Himalayan salt, provided the largest contribution to the Recommended Dietary Allowance (RDA) of calcium, potassium, magnesium, iron, and manganese. The contribution of S5 to the RDA of calcium in females and males ranged between 2.65-2.79%. In comparison, S11, a sea salt, contributed only 0.04% to the RDA of calcium. For potassium, S5 contributed between 0.78% and 1.42% in females, while males in 0.78% to 1.08%. Salts S1 and S2 had almost negligible contributions to daily potassium intake. The contribution of S5 to the RDA of magnesium was between 8.09-8.36% in females and 5.97-7.16% in males. In contrast, S2 only contributed 0.06% in females and 0.05% in males. The contribution of S5 to the RDA of iron was 2.24-2.52% in females and 3.67-5.05% in males. Regarding iron, S5's contribution to the RDA was between 2.24% and 2.52% in females and between 3.67% and 5.05% in males. In comparison, S11's contribution was almost one-fifteenth of S5's. Although the contributions of salts to the daily RDA are different, it is seen that salt consumption contributes minimally to overall daily nutritional requirements.

This study provides valuable insights into the essential and non-essential elements content of table salts commonly consumed in Türkiye. While Himalayan salts exhibited higher concentrations of essential elements, their contribution to daily nutritional intake remains limited. Importantly, the HRA confirmed that the determined element levels in the analyzed salts do not pose significant non-carcinogenic risks. However, continued monitoring and regulation of salt sources are essential to ensure consumer safety. Future research should focus on the potential interactions between essential and non-essential elements in food products and their cumulative health effects over time.

Consequently, in this study, the essential and non-essential elements levels in 11 salt samples frequently consumed in Türkiye were found to comply with the Dietary Reference Intake Levels and Codex Limits. While no adverse health risks were identified based on the HRA in terms of analysed elements it remains crucial to perform thorough element analyses before these salts are made available for consumption to ensure public health safety. Although the examined salts contained varying amounts of elements, their contribution to meeting daily adequate intake levels appears to be minimal.

Table 4. EDI, CDI, THQ, and HI levels of elements from salt across different age groups

Salts	Element	Estimated Daily Intake			Chronic Daily Intake			Target Hazard Quotient			Hazard Index		
		Age (years)			Age (years)			Age (years)			Age (years)		
		≥21	16 to <21	11 to <16	≥21	16 to <21	11 to <16	≥21	16 to <21	11 to <16	≥21	16 to <21	11 to <16
S1	Al	9.70^{E-05}	1.08^{E-04}	1.36^{E-04}	8.48^{E-05}	1.06^{E-04}	1.68^{E-04}	8.48^{E-05}	1.06^{E-04}	6.64^{E-04}	0.01	0.01	0.02
	B	7.70^{E-06}	8.55^{E-06}	1.08^{E-05}	6.69^{E-06}	8.36^{E-06}	1.33^{E-05}	3.35^{E-04}	4.18^{E-04}	1.68^{E-04}			
	Cr	7.50^{E-05}	8.41^{E-05}	1.06^{E-04}	6.58^{E-05}	8.22^{E-05}	1.31^{E-04}	4.39^{E-05}	5.48^{E-05}	8.70^{E-05}			
	Fe	3.00^{E-03}	3.40^{E-03}	4.29^{E-03}	2.67^{E-03}	3.33^{E-03}	5.29^{E-03}	4.16^{E-03}	5.20^{E-03}	8.26^{E-03}			
	Mn	6.10^{E-05}	6.84^{E-05}	8.62^{E-05}	5.36^{E-05}	6.69^{E-05}	1.06^{E-04}	3.83^{E-04}	4.78^{E-04}	7.59^{E-04}			
	Ni	1.20^{E-04}	1.35^{E-04}	1.71^{E-04}	1.06^{E-04}	1.32^{E-04}	2.10^{E-04}	5.30^{E-03}	6.62^{E-03}	1.05^{E-02}			
S2	Al	2.80^{E-05}	3.13^{E-05}	3.95^{E-05}	2.45^{E-05}	3.06^{E-05}	4.87^{E-05}	2.45^{E-05}	3.06^{E-05}	1.55^{E-03}	0.01	0.01	0.02
	B	1.80^{E-05}	1.99^{E-05}	2.51^{E-05}	1.56^{E-05}	1.95^{E-05}	3.10^{E-05}	7.81^{E-04}	9.75^{E-04}	4.87^{E-05}			
	Cr	8.50^{E-05}	9.54^{E-05}	1.20^{E-04}	7.47^{E-05}	9.33^{E-05}	1.48^{E-04}	4.98^{E-05}	6.22^{E-05}	9.89^{E-05}			
	Fe	1.50^{E-03}	1.65^{E-03}	2.08^{E-03}	1.29^{E-03}	1.61^{E-03}	2.56^{E-03}	2.02^{E-03}	2.52^{E-03}	4.01^{E-03}			
	Mn	7.80^{E-06}	8.69^{E-06}	1.10^{E-05}	6.81^{E-06}	8.50^{E-06}	1.35^{E-05}	4.86^{E-05}	6.07^{E-05}	9.64^{E-05}			
	Ni	1.30^{E-04}	1.42^{E-04}	1.80^{E-04}	1.12^{E-04}	1.39^{E-04}	2.21^{E-04}	5.58^{E-03}	6.96^{E-03}	1.11^{E-02}			
S3	Al	2.90^{E-05}	3.28^{E-05}	4.13^{E-05}	2.57^{E-05}	3.20^{E-05}	5.09^{E-05}	2.57^{E-05}	3.20^{E-05}	9.41^{E-03}	0.01	0.01	0.02

	B	1.10^{E-04}	1.21^{E-04}	1.53^{E-04}	9.48^{E-05}	1.18^{E-04}	1.88^{E-04}	4.74^{E-03}	5.92^{E-03}	5.09^{E-05}			
	Cr	7.00^{E-05}	7.84^{E-05}	9.88^{E-05}	6.14^{E-05}	7.66^{E-05}	1.22^{E-04}	4.09^{E-05}	5.11^{E-05}	8.11^{E-05}			
	Fe	6.70^{E-04}	7.49^{E-04}	9.45^{E-04}	5.87^{E-04}	7.33^{E-04}	1.16^{E-03}	9.17^{E-04}	1.14^{E-03}	1.82^{E-03}			
	Mn	1.40^{E-05}	1.51^{E-05}	1.90^{E-05}	1.18^{E-05}	1.48^{E-05}	2.35^{E-05}	8.45^{E-05}	1.05^{E-04}	1.68^{E-04}			
	Ni	5.90^{E-05}	6.55^{E-05}	8.26^{E-05}	5.13^{E-05}	6.41^{E-05}	1.02^{E-04}	2.57^{E-03}	3.20^{E-03}	5.09^{E-03}			
S4	Al	3.30^{E-04}	3.72^{E-04}	4.69^{E-04}	2.91^{E-04}	3.64^{E-04}	5.78^{E-04}	2.91^{E-04}	3.64^{E-04}	1.01^{E-02}	0.01	0.01	0.02
	B	1.20^{E-04}	1.30^{E-04}	1.63^{E-04}	1.02^{E-04}	1.27^{E-04}	2.01^{E-04}	5.08^{E-03}	6.34^{E-03}	5.78^{E-04}			
	Cr	9.70^{E-05}	1.08^{E-04}	1.36^{E-04}	8.48^{E-05}	1.06^{E-04}	1.68^{E-04}	5.65^{E-05}	7.06^{E-05}	1.12^{E-04}			
	Fe	1.50^{E-03}	1.70^{E-03}	2.14^{E-03}	1.33^{E-03}	1.66^{E-03}	2.64^{E-03}	2.08^{E-03}	2.59^{E-03}	4.12^{E-03}			
	Mn	6.80^{E-05}	7.59^{E-05}	9.57^{E-05}	5.95^{E-05}	7.42^{E-05}	1.18^{E-04}	4.25^{E-04}	5.30^{E-04}	8.43^{E-04}			
	Ni	5.50^{E-05}	6.13^{E-05}	7.72^{E-05}	4.80^{E-05}	5.99^{E-05}	9.52^{E-05}	2.40^{E-03}	2.99^{E-03}	4.76^{E-03}			
S5	Al	7.10^{E-04}	7.98^{E-04}	1.01^{E-03}	6.25^{E-04}	7.80^{E-04}	1.24^{E-03}	6.25^{E-04}	7.80^{E-04}	3.05^{E-02}	0.03	0.04	0.06
	B	3.50^{E-04}	3.93^{E-04}	4.96^{E-04}	3.08^{E-04}	3.84^{E-04}	6.11^{E-04}	1.54^{E-02}	1.92^{E-02}	1.24^{E-03}			
	Cr	6.40^{E-05}	7.12^{E-05}	8.98^{E-05}	5.58^{E-05}	6.96^{E-05}	1.11^{E-04}	3.72^{E-05}	4.64^{E-05}	7.38^{E-05}			
	Fe	5.00^{E-03}	5.64^{E-03}	7.11^{E-03}	4.42^{E-03}	5.52^{E-03}	8.76^{E-03}	6.90^{E-03}	8.62^{E-03}	1.37^{E-02}			
	Mn	1.60^{E-04}	1.83^{E-04}	2.31^{E-04}	1.44^{E-04}	1.79^{E-04}	2.85^{E-04}	1.03^{E-03}	1.28^{E-03}	2.03^{E-03}			
	Ni	1.80^{E-04}	1.99^{E-04}	2.51^{E-04}	1.56^{E-04}	1.95^{E-04}	3.10^{E-04}	7.80^{E-03}	9.74^{E-03}	1.55^{E-02}			
S6	Al	1.30^{E-04}	1.47^{E-04}	1.85^{E-04}	1.15^{E-04}	1.43^{E-04}	2.28^{E-04}	1.15^{E-04}	1.43^{E-04}	4.09^{E-03}	0.01	0.02	0.03
	B	4.70^{E-05}	5.27^{E-05}	6.64^{E-05}	4.13^{E-05}	5.15^{E-05}	8.19^{E-05}	2.06^{E-03}	2.58^{E-03}	2.28^{E-04}			
	Cr	8.20^{E-05}	9.12^{E-05}	1.15^{E-04}	7.14^{E-05}	8.91^{E-05}	1.42^{E-04}	4.76^{E-05}	5.94^{E-05}	9.44^{E-05}			
	Fe	4.00^{E-03}	4.46^{E-03}	5.62^{E-03}	3.49^{E-03}	4.36^{E-03}	6.93^{E-03}	5.46^{E-03}	6.82^{E-03}	1.08^{E-02}			
	Mn	3.80^{E-05}	4.25^{E-05}	5.35^{E-05}	3.32^{E-05}	4.15^{E-05}	6.60^{E-05}	2.37^{E-04}	2.96^{E-04}	4.71^{E-04}			
	Ni	1.40^{E-04}	1.60^{E-04}	2.01^{E-04}	1.25^{E-04}	1.56^{E-04}	2.48^{E-04}	6.25^{E-03}	7.80^{E-03}	1.24^{E-02}			
S7	Al	1.70^{E-05}	1.85^{E-05}	2.33^{E-05}	1.45^{E-05}	1.81^{E-05}	2.88^{E-05}	1.45^{E-05}	1.81^{E-05}	1.60^{E-03}	0.00	0.00	0.01
	B	1.80^{E-05}	2.07^{E-05}	2.60^{E-05}	1.62^{E-05}	2.02^{E-05}	3.21^{E-05}	8.09^{E-04}	1.01^{E-03}	2.88^{E-05}			
	Cr	8.90^{E-05}	9.97^{E-05}	1.26^{E-04}	7.81^{E-05}	9.75^{E-05}	1.55^{E-04}	5.21^{E-05}	6.50^{E-05}	1.03^{E-04}			
	Fe	8.20^{E-04}	9.16^{E-04}	1.15^{E-03}	7.17^{E-04}	8.96^{E-04}	1.42^{E-03}	1.12^{E-03}	1.40^{E-03}	$2..22^{E-03}$			
	Mn	7.90^{E-06}	8.83^{E-06}	1.11^{E-05}	6.92^{E-06}	8.64^{E-06}	1.37^{E-05}	4.94^{E-05}	6.17^{E-05}	9.80^{E-05}			
	Ni	4.10^{E-05}	4.56^{E-05}	5.75^{E-05}	3.57^{E-05}	4.46^{E-05}	7.08^{E-05}	1.79^{E-03}	2.23^{E-03}	3.54^{E-03}			
S8	Al	1.30^{E-04}	7.98^{E-05}	1.01^{E-04}	6.25^{E-05}	7.80^{E-05}	1.24^{E-04}	6.25^{E-05}	7.80^{E-05}	1.54^{E-02}	0.01	0.01	0.02
	B	3.40^{E-05}	1.98^{E-04}	2.50^{E-04}	1.55^{E-04}	1.94^{E-04}	3.08^{E-04}	7.75^{E-03}	9.68^{E-03}	1.24^{E-04}			
	Cr	1.30^{E-04}	8.97^{E-05}	1.13^{E-04}	7.03^{E-05}	8.77^{E-05}	1.39^{E-04}	4.69^{E-05}	5.85^{E-05}	9.30^{E-05}			
	Fe	3.30^{E-04}	7.78^{E-04}	9.80^{E-04}	6.09^{E-04}	7.60^{E-04}	1.21^{E-03}	9.52^{E-04}	1.19^{E-03}	1.89^{E-03}			
	Mn	9.20^{E-05}	2.76^{E-05}	3.48^{E-05}	2.16^{E-05}	2.70^{E-05}	4.29^{E-05}	1.55^{E-04}	1.93^{E-04}	3.07^{E-04}			
	Ni	7.80^{E-05}	3.70^{E-05}	4.67^{E-05}	2.90^{E-05}	3.62^{E-05}	5.75^{E-05}	1.45^{E-03}	1.81^{E-03}	2.88^{E-03}			
S9	Al	9.70^{E-05}	1.27^{E-04}	1.60^{E-04}	9.93^{E-05}	1.24^{E-04}	1.97^{E-04}	9.93^{E-05}	1.24^{E-04}	9.96^{E-03}	0.01	0.01	0.02
	B	7.70^{E-06}	1.28^{E-04}	1.62^{E-04}	1.00^{E-04}	1.25^{E-04}	1.99^{E-04}	5.02^{E-03}	6.27^{E-03}	1.97^{E-04}			
	Cr	7.50^{E-05}	1.52^{E-04}	1.92^{E-04}	1.19^{E-04}	1.49^{E-04}	2.37^{E-04}	7.96^{E-05}	9.93^{E-05}	1.58^{E-04}			
	Fe	3.00^{E-03}	1.14^{E-03}	1.43^{E-03}	8.91^{E-04}	1.11^{E-03}	1.77^{E-03}	1.39^{E-03}	1.74^{E-03}	2.76^{E-03}			
	Mn	6.10^{E-05}	1.85^{E-05}	2.33^{E-05}	1.45^{E-05}	1.81^{E-05}	2.88^{E-05}	1.04^{E-04}	1.29^{E-04}	2.06^{E-04}			
	Ni	1.20^{E-04}	4.13^{E-05}	5.21^{E-05}	3.24^{E-05}	4.04^{E-05}	6.42^{E-05}	1.62^{E-03}	2.02^{E-03}	3.21^{E-03}			
S10	Al	2.80^{E-05}	7.27^{E-05}	9.16^{E-05}	5.69^{E-05}	7.10^{E-05}	1.13^{E-04}	5.69^{E-05}	7.10^{E-05}	4.20^{E-02}	0.03	0.03	0.05
	B	1.80^{E-05}	5.41^{E-04}	6.82^{E-04}	4.24^{E-04}	5.29^{E-04}	8.41^{E-04}	2.12^{E-02}	2.65^{E-02}	1.13^{E-04}			
	Cr	8.50^{E-05}	1.48^{E-04}	1.87^{E-04}	1.16^{E-04}	1.45^{E-04}	2.30^{E-04}	7.74^{E-05}	9.66^{E-05}	1.53^{E-04}			
	Fe	1.50^{E-03}	9.52^{E-04}	1.20^{E-03}	7.45^{E-04}	9.30^{E-04}	1.48^{E-03}	1.16^{E-03}	1.45^{E-03}	2.31^{E-03}			
	Mn	7.80^{E-06}	2.42^{E-05}	3.05^{E-05}	1.90^{E-05}	2.37^{E-05}	3.76^{E-05}	1.35^{E-04}	1.69^{E-04}	2.69^{E-04}			
	Ni	1.30^{E-04}	5.70^{E-05}	7.18^{E-05}	4.46^{E-05}	5.57^{E-05}	8.85^{E-05}	2.23^{E-03}	2.79^{E-03}	4.43^{E-03}			
S11	Al	2.90^{E-05}	1.44^{E-04}	1.81^{E-04}	1.13^{E-04}	1.41^{E-04}	2.24^{E-04}	1.13^{E-04}	1.41^{E-04}	2.99^{E-03}	0.01	0.01	0.01
	B	1.10^{E-04}	3.85^{E-05}	4.85^{E-05}	3.01^{E-05}	3.76^{E-05}	5.98^{E-05}	1.51^{E-03}	1.88^{E-03}	2.24^{E-04}			
	Cr	7.00^{E-05}	1.50^{E-04}	1.89^{E-04}	1.17^{E-04}	1.46^{E-04}	2.32^{E-04}	7.81^{E-05}	9.75^{E-05}	1.55^{E-04}			
	Fe	6.70^{E-04}	3.65^{E-04}	4.60^{E-04}	2.86^{E-04}	3.57^{E-04}	5.67^{E-04}	4.46^{E-04}	5.57^{E-04}	8.85^{E-04}			
	Mn	1.40^{E-05}	1.03^{E-04}	1.29^{E-04}	8.03^{E-05}	1.00^{E-04}	1.59^{E-04}	5.74^{E-04}	7.16^{E-04}	1.14^{E-03}			
	Ni	5.90^{E-05}	8.69^{E-05}	1.10^{E-04}	6.81^{E-05}	8.50^{E-05}	1.35^{E-04}	3.40^{E-03}	4.25^{E-03}	6.75^{E-03}			

Table 5. Percentages of daily dietary reference values met by the salts analyzed in this study

Contribution of salts to dietary reference values (%)							
		Female			Male		
	Salts	a	b	c	a	b	c
Ca	S1	1.99	1.89	1.89	1.99	1.89	1.89
	S2	1.99	1.89	1.89	1.99	1.89	1.89
	S3	0.88	0.84	0.84	0.88	0.84	0.84
	S4	0.71	0.68	0.68	0.71	0.68	0.68
	S5	2.79	2.65	2.65	2.79	2.65	2.65
	S6	2.17	2.07	2.07	2.17	2.07	2.07
	S7	0.53	0.51	0.51	0.53	0.51	0.51
	S8	0.37	0.35	0.35	0.37	0.35	0.35
	S9	0.42	0.40	0.40	0.42	0.40	0.40
	S10	0.46	0.44	0.44	0.46	0.44	0.44
	S11	0.04	0.04	0.04	0.04	0.04	0.04
K	S1	0.00	0.00	0.00	0.00	0.00	0.00
	S2	0.00	0.00	0.00	0.00	0.00	0.00

	S3	0.01	0.01	0.02	0.01	0.01	0.01
	S4	0.28	0.21	0.37	0.28	0.21	0.28
	S5	1.05	0.78	1.42	1.05	0.78	1.08
	S6	0.25	0.18	0.33	0.25	0.18	0.25
	S7	0.02	0.01	0.02	0.02	0.01	0.02
	S8	0.02	0.01	0.03	0.02	0.01	0.02
	S9	0.03	0.02	0.04	0.03	0.02	0.03
	S10	0.05	0.04	0.07	0.05	0.04	0.06
	S11	0.02	0.01	0.03	0.02	0.01	0.02
Mg	S1	0.07	0.07	0.06	0.05	0.06	0.05
	S2	0.06	0.06	0.06	0.05	0.05	0.05
	S3	0.09	009	0.09	0.08	0.08	0.06
	S4	4.91	4.91	4.75	4.09	4.21	3.51
	S5	8.36	8.36	8.09	6.96	7.16	5.97
	S6	1.98	1.98	1.92	1.65	1.70	1.42
	S7	0.11	0.11	0.11	0.09	0.10	0.08
	S8	0.81	0.81	0.79	0.68	0.70	0.58
	S9	0.70	0.70	0.68	0.58	0.60	0.50
	S10	2.06	2.06	1.99	1.72	1.77	1.47
	S11	0.30	0.30	0.29	0.25	0.26	0.22
Fe	S1	1.52	1.52	1.35	2.22	2.22	3.05
	S2	0.74	0.74	0.66	1.07	1.07	1.48
	S3	0.34	0.34	0.30	0.49	0.49	0.67
	S4	0.76	0.76	0.67	1.10	1.10	1.52
	S5	2.52	2.52	2.24	3.67	3.67	5.05
	S6	2.00	2.00	1.77	2.90	2.90	3.99
	S7	0.41	0.41	0.36	0.60	0.60	0.82
	S8	0.35	0.35	0.31	0.51	0.51	0.70
	S9	0.51	0.51	0.45	0.74	0.74	1.02
	S10	0.43	0.43	0.38	0.62	0.62	0.85
	S11	0.16	0.16	0.15	0.24	0.24	0.33
Mn	S1	0.16	0.16	0.27	0.16	0.16	0.21
	S2	0.02	0.02	0.03	0.02	0.02	0.03
	S3	0.04	0.04	0.06	0.04	0.04	0.05
	S4	0.18	0.18	0.30	0.18	0.18	0.24
	S5	0.44	0.44	0.73	0.44	0.44	0.57
	S6	0.10	0.10	0.17	0.10	0.10	0.13
	S7	0.02	0.02	0.04	0.02	0.02	0.03
	S8	0.07	0.07	0.11	0.07	0.07	0.09
	S9	0.04	0.04	0.07	0.04	0.04	0.06
	S10	0.06	0.06	0.10	0.06	0.06	0.08
	S11	0.24	0.24	0.41	0.24	0.24	0.32

Values are given in %. a: EFSA (2017) (Population reference intakes and adequate intakes for minerals, for ≥18 years). b: Republic of Türkiye Ministry of Health-Dietary Guideline for Türkiye (2022) (Population reference intakes and adequate intakes for minerals, for 18-70 years), c: Food and Nutrition Board (2019) Recommended dietary allowances and adequate intakes, elements, for 19-50 years).

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The growing issue of bread wastage presents significant challenges to food security, environmental sustainability, and economic stability, particularly in regions like Tunisia. This study investigated a comprehensive strategy for the valorization of stale bread through its incorporation into *Maachech*, a traditional Tunisian cookie. The objective of the present work was to develop a sustainable, nutritious and sensorically acceptable food product within a circular economy framework.

Stale bread was staled at ambient temperature for 72 hours, processed into whole and crumb fractions, and subsequently milled into flour. Six different *Maachech* cookie formulations were prepared, featuring incremental substitution levels of wheat flour with stale bread flour (F0:0%, F1:10%, F2:20%, F3:30%, F4:40%, and F5:100%). Proximate composition (moisture, protein, fat, and sugars), CIE *Lab* color parameters (L*, a*, b*, Chroma, ΔE), techno-functional properties and microbial loads were determined for stale bread flour and cookie formulas. *Maachech* cookie caloric values were calculated utilizing the Atwater system. A hedonic sensory evaluation was performed with a panel of 61 volunteer consumers (mean age 25.7 ± 6.5 years, 96% female, university educated, 60% aware of environment, climate change and food waste issues) using a 7-point scale. Post-tasting, panelists' willingness to buy and underlying motivations were assessed via direct survey.

Analysis of the 3-day stale bread revealed the following characteristics: Humidity 28.39±0.23%, Dry Extract 75.22±0.26 g/100g, Proteins 6.25±0.02 g/100g, Fat 1.8±0.01 g/100g, Sugars 0.54±0.01 g/100g, Reducing Sugars 1.39±0.14 g/100g, and Acidity 0.0270±0.0001 g of lactic acid/ 100g of bread. Microbiological analysis indicated that the 3-day stale bread conformed to established food safety standards. It also exhibited high oil and water holding performance, making it suitable for reprocessing into flour for cookie development.

Findings showed that 30% substitution level (F3) was found to offer the best compromise between technological performance and consumer acceptability. The F3 *Maachech* cookies had a fat content of 27.62 g/100g, protein content of 18.7 g/100g, reducing sugars at 25 g/100g, and a total calorie value of 336.13 kcal/100g. Functionally, they displayed a water holding capacity of 10 g/g, an oil holding capacity of 7 g/g, and were microbiologically safe. Color values remained within the acceptable range (ΔE ≈ 2.3) at this level of incorporation, with visual differences only increasing at higher substitutions.

Sensory analysis confirmed F3 as the most preferred product in terms of texture, taste, appearance, achieving a mean global appreciation score of 5.96/7 and ranking first by the majority of the panel. Panelist survey analysis indicated that all (100%) expressed a willingness to buy *Maachech* cookies made with stale bread flour. The main motivations cited were: fighting food waste (83.6%), environmental responsibility (77%), support for local and artisanal production (70.5%), curiosity for new flavors and textures (63.9%), and religious values (16.4%).

Overall, this study demonstrated the feasibility and market acceptance of reusing stale bread in traditional cookie recipes, offering a practical integrated model for reducing bread waste while maintaining product quality, safety, and nutritional value. Through scientific validation and consumer-centered formulation, *Maachech* becomes a powerful example of zero-waste innovation rooted in tradition—an approach replicable in similar food systems worldwide.

Key Words: *Bread waste valorization, Traditional cookies, Sustainable food production, Sensory acceptability, Circular economy*

ID: 741

Effect of Nanoparticles Application on the Germination and Growth of Tunisian Durum Wheat Varieties (Dhabee, Kareem and Inrat100) Under Simulated water Stress Conditions

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Abstract

This study discussed the effect of five sorts of nanoparticles, SiO2, ZrO2, MgO, ZnO, and TiO2 in the germination and growth of three varieties of Tunisian durum wheat (Triticum turgidum subsp. durum Desf.) (Dhabee, Inrat100, and Kreem) under the simulated stress conditions using poly ethanol glycol (PEG6000). Moreover, in this study, two levels of stress conditions were evaluated compared to control (distilled water). Also, the study checked the different concentrations of nanoparticles to determine their results on the germination, the root length, and the shoot length. The results declared that the water stress resulted in a significant decrease in the germination and growth rates. In addition to that the nanoparticles (TiO2, ZnO) get the highest efficiency in decreasing the side effects of the stress. The TiO2 NPs at the concentration of 100 proved their efficiency in enhancing germination and growth special under severe stress conditions of -3 bar. Furthermore, the varieties showed significant differences in stress conditions as Inrat100 declared exceeding in stress resistance. These results highlighted the possibility of using the NPs, to improve the performance of crops under drought conditions in rainfed Agriculture.

Key Words: *Nanoparticles, Durum wheat, Water stress, Germination,Sshoot length*

ID: 742

Integrated Agriculture-Aquaculture Systems for sustainable development in Rural Nepal

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Abstract

Food security with sustainable development is a major issue being faced by the ever growing population in the world. Integrated Agriculture- Aquaculture (IAA) systems are increasingly recognized as vital for food and nutrition security particularly in the face of global challenges such as climate change, resource scarcity, and food insecurity. By harmoniously integrating crop farming with aquaculture practices, IAA systems enable efficient recycling of nutrients and water, reduce reliance on external inputs, and enhance overall farm productivity and resilience. Further, the integration of aquaculture into agricultural landscapes offers a practical pathway to circular economy practices and climate-smart agriculture. Aquaculture is a fast growing food-production sector that recently overtook fisheries as the main source of fish for human consumption. In Nepal different aquatic systems represent a total of 252 fish species. Among them 236 species are indigenous while 16 species are exotic. These species belong to 15 orders, 40 families and 120 genera. Carps of the order Cypriniformes are the major fishes cultivated in Nepal. These includes Indian Major Carps; Rohu (*Labeo rohita*), Mrigal (*Cirrhina mrigala*), and Chinese Major carps; Grass carp (*Ctenopharyngodon idella*), Silver carp (*Hypophthalmichthys molitrix*) and Bighead carp (*Hypophthalmichthys nobilis*). Two varieties of Common carp; Scale carp (*Cyprinus carpio var. communis*) and Mirror carp (*Cyprinus carpio var. specularis*) are cultivated also. Recently exotic catfish Pangas (*Pangasianodon hypophthalmus*) and exotic perch Nile tilapia (*Oreochromis niloticus*) are cultivated also. Annual fish production of Nepal is 113736 metric tons with the contribution of 92736 metric tons from aquaculture and 21000 metric tons from the inland capture fisheries, indicating per capita fish production 3.8 kg only. Pond fish culture accounts for 72.3% of the current total fish production. The Terai belt which makes up 88% of the entire pond area, is crucial to fish production due to its favourable environment. The support from the government certainly helped the expansion of fish farming to fulfil its potential to meet the national demand for nutritional support of the people and employment opportunities towards sustainable development of the nation.

ID: 743

Assessing the Economic Performance of Catfish Farming in Nsukka and Enugu Metropolis, Nigeria: A Comparative Perspective

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Abstract

Despite the significant contribution of catfish farming to Nigeria's agricultural sector, there is limited research on its economic viability and opportunities. This study presents a comparative analysis of the economic performance of catfish farming in both the Nsukka Local Government Area (LGA) and Enugu Metropolis, Nigeria. Specifically, it compared the socioeconomic characteristics of catfish farmers, evaluated the profitability of catfish production, and identified the constraints faced by farmers in these locations. A multistage sampling technique was used to select 120 respondents, and primary data were gathered using a structured questionnaire. Descriptive statistics and profitability indicators were employed to achieve the objectives. The results indicated that most catfish farmers in both locations are young, married, and have a formal education. The findings also revealed that catfish farming is a profitable venture in both Nsukka LGA and Enugu Metropolis, with mean gross margins of ₦662,534.45 and ₦861,733.22, respectively. The return on investment (ROI) for catfish farmers in Nsukka LGA was 1.09. In contrast, the ROI for Enugu Metropolis was 1.40, demonstrating greater profitability in that area. However, the enterprise faces significant challenges, including high feed costs, elevated interest rates on bank loans, inadequate access to quality fingerlings, and high-water supply costs. The study recommends strategic interventions to address these challenges and enhance the profitability and sustainability of catfish farming in the areas studied, including input cost management, better access to credit, and government support for research and development.

Keywords: *Catfish farming, Economic performance, Profitability, Investment, Nigeria.*

Introduction

Aquaculture has emerged as a vital sector in Nigeria's agricultural economy, playing a significant role in enhancing food security, providing a sustainable source of protein, generating employment, and contributing to household income for millions of people in urban and rural areas (Ogunji & Wuertz, 2023; Falola et al., 2022). The sector has witnessed substantial growth over the past few decades, particularly in urban and peri-urban regions where market access and infrastructure support aquaculture development. This growth has positioned Nigeria as a leading aquaculture producer in Sub-Saharan Africa (Adeleke et al., 2020; FAO, 2022), with southeastern states like Enugu experiencing a notable surge in catfish farming activities, driven by the proliferation of small and medium-scale farms. Among the various aquaculture practices, catfish farming has gained prominence due to increasing population, rising consumer preference for fish protein, declining capture fisheries, adaptability to diverse local environmental conditions, and relatively low production costs, as well as its fast growth rate (Abdel-Hady et al., 2024; Manyise et al., 2024; Mukaila et al, 2023). Catfish (*Clarias gariepinus* and *Heterobranchus spp.)* is one of the most cultivated fish species, contributing significantly to food security and livelihoods, particularly in urban and peri-urban areas in Nigeria (Olagunju, 2024; Adeleke et al, 2020).

Within Nigeria, different geographical regions demonstrate varying levels of catfish farming development and economic performance based on local conditions, market dynamics, and resource availability (Engle et al., 2022; Olagunju et al., 2022). Southeastern Nigeria, particularly Enugu State, has witnessed a proliferation of catfish farms, with Nsukka and Enugu Metropolis becoming key production hubs (Umaru et al., 2021). Nsukka and Enugu metropolis represent two distinct centers in southeastern Nigeria with different socioeconomic profiles, infrastructure development, and market characteristics that potentially influence catfish farming operations. Nsukka, a university town, characterized by its rural settings and limited market infrastructure, contrasts with Enugu metropolis, an urban centre, which serves as a major administrative and commercial hub in the region with a more diverse economic landscape and potentially different market demands and access to resources. These differences may significantly impact the structure, operation, and economic outcomes of catfish farming enterprises in both locations.

In addition, earlier studies (Arifa et al., 2022; Kumar et al., 2020; Diatin et al., 2020; Olagunju et al., 2022; Mukaila et al., 2023) showed several factors can influence the economic performance of catfish farming, including the socioeconomic characteristics of the farmers, the scale and intensity of production, access to inputs and credit, market dynamics, and the prevalence of constraints such as disease outbreaks, high feed costs, poor water management and inadequate infrastructure influence production efficiency, profitability, and overall economic viability. Thus, while catfish farming has proven profitable and contributes significantly to local economies in both locations, its operational dynamics, farmer characteristics, and challenges are likely shaped by their distinct

environments. Similarly, despite its growth, Ajagbe et al. (2024), Mukaila et al. (2023), and Mbokane et al. (2022) noted that catfish farming faces persistent challenges, including high feed costs, limited access to credit, inadequate water management, and inconsistent government policies, which vary across locations due to differences in infrastructure, market access, and farming practices.

Existing studies (Olagunju et al., 2022; Onyekuru et al., 2019; Akoh et al., 2025; Akure et al., 2024; Cheatham et al., 2023; Adelesi & Baruw, 2022) on catfish farming in Nigeria have largely focused on general profitability analyses or technical production challenges, with limited comparative studies specifically examining the socioeconomic and economic nuances between locations like Nsukka and Enugu Metropolis. Understanding these location-specific differences is crucial for formulating targeted policies and interventions to optimize resource utilization, improve market access, mitigate production risks for catfish farmers, enhance productivity, and the sustainability of the sector. This study, therefore, seeks to address this gap by comparatively assessing the socioeconomic profiles of catfish farmers in Nsukka and Enugu Metropolis, evaluating the profitability of their production systems, and identifying the key constraints they face. By providing evidence-based insights into these critical aspects, this research aims to contribute to the sustainable development of catfish farming in Enugu State and offer valuable lessons for similar agro-economic settings across Nigeria. The findings will be beneficial for policymakers, development agencies, extension services, prospective and current farmers, and other stakeholders in the aquaculture value chain.

Materials and Methods

The study was carried out in Enugu Metropolis and Nsukka Local Government Area (LGA) of Enugu State, Nigeria. Enugu metropolis is the capital city of Enugu State, and it comprises Enugu East, Enugu North, and Enugu South LGAs. Enugu State lies between latitudes 5°56'N and 7°36'N and longitudes 6°53'E and 7°55'E of the Greenwich Meridian (Enugu State Agricultural Development Project, ENADEP, 2009). A multi-stage sampling technique was used to select catfish farmers from Enugu Metropolis and Nsukka (LGA). The first stage was a purposive selection of six communities with a large number of catfish farmers from Enugu Metropolis and Nsukka LGA. The second and final stage was a random selection of 10 catfish farmers from the list of farmers in each of the 12 communities, giving a total of 120 respondents for the study, that is, 60 in Nsukka LGA and 60 in Enugu Metropolis.

Primary data was used for the study and was collected from the catfish farmers using a well-structured questionnaire. The questionnaire captured information such as the socio-economic characteristics of the respondents, costs incurred, and revenues obtained in catfish rearing and production constraints faced by the farmers. Descriptive statistics such as frequency distribution and percentages, gross margin, and net farm income techniques were used to achieve the objectives.

Model Specifications

Gross margin analysis was expressed as:

GM = TR -TVC

Where:
GM = Gross Margin (₦)
TR = Total Revenue (₦)

TVC = (Total Variable Cost) (₦)
NFI (Net Farm Income) = GM -TFC
TFC = Total Fixed Cost

$$\text{Return on Investment} = \frac{GM}{TVC}$$

Results and Discussion

Socio-economic characteristics of catfish farmers

The study revealed that catfish farming in both Nsukka LGA and Enugu Metropolis is predominantly male-dominated, with males constituting 68.3% and 76.7% of the respondents, respectively. The male dominance in catfish farming suggests potential barriers to women's participation, highlighting the need for initiatives to promote gender inclusivity. In terms of marital status, the majority of the respondents were married, accounting for 63.3% in Nsukka LGA and 68.3% in Enugu Metropolis. The high percentage of married respondents implies that family responsibilities may influence farming decisions, labour allocation, and income management. The age distribution showed that most farmers in both locations fell within the 21-40 age range, with 45% in Nsukka LGA and 51.7% in Enugu Metropolis. The mean ages of 41 and 43 years in Nsukka LGA and Enugu Metropolis, respectively, suggest that the catfish farmers are relatively young and energetic, which could contribute to innovation, productivity, and sustainability of the catfish business. The result aligns with a study by Omeje *et al.* (2021) among

catfish farmers in Kainji Lake Basin, Nigeria. Regarding household size, the majority of respondents in both locations had household sizes ranging from 1 to 4 persons, accounting for 48.3% in Nsukka LGA and 60% in Enugu Metropolis. The mean household sizes were 6 and 5 persons in Nsukka LGA and Enugu Metropolis, respectively. The result is in agreement with Jimmy et al (2024) and Gbigbi (2021) that the mean household size of Catfish farmers is between 6 and 8. The educational qualifications of catfish farmers differed between Nsukka LGA and Enugu Metropolis. In Nsukka, 3.3% had no formal education, while in Enugu Metropolis, all farmers had formal education. The mean years of schooling were 11 years in Nsukka and 13 years in Enugu, indicating that the farmers can manage catfish production effectively. However, additional training or support could further enhance productivity.

Table 1: Socioeconomic Characteristics of the Catfish Farmers

Socio-economic Characteristics	Nsukka (*n=60*)		Enugu (*n=60*)	
	Frequency	Percentage	Frequency	Percentage
Gender				
Male	41	68.3	46	76.7
Female	19	31.7	14	23.3
Marital status				
Married	38	63.3	41	68.3
Single	19	31.7	13	21.7
Divorced	1	1.7	2	3.3
Widowed	2	3.3	4	6.7
Age				
≤20	11	18.3	14	23.3
21-40	27	45.0	31	51.7
41-60	14	23.3	11	18.3
61-80	8	13.4	4	6.7
Mean	*41.31 years*		*43.73 years*	
Household size				
1– 4	29	48.3	36	60.0
5 – 8	18	30.0	21	35.0
9 -12	13	21.7	3	5
Mean	*6.53 persons*		*5.88 persons*	
Education qualification				
No formal Education	2	3.3	-	
Primary	17	28.3	13	21.7
Secondary	31	51.7	35	58.3
Tertiary	10	16.7	12	20
Years of education				
0 – 6	19	31.7	25	41.7
7 – 12	34	56.7	30	50
≥13	7	11.6	5	8.3
Mean	*11.82 years*		*13.67 years*	
Years of experience				
≤10	16	26.7	12	20.0
11 – 15	33	55.0	39	65.0
≥16	11	18.3	9	15.0
Mean	*11.71 years*		*12.91 years*	
Mode of Operation				
Full time	38	63.3	43	71.7
Part-time	22	36.7	17	28.3
Size of Operation				
Small-scale	22	36.7	14	23.4
Medium-scale	35	58.3	41	68.3
Large-scale	3	5.0	5	8.3
Monthly Income				
30,000-60,000	9	15.0	4	6.7
61,000-100,000	39	65.0	41	68.3
101,000-250,000	12	20.0	15	25
Mean	89,151.75			105,148.02

The result is consistent with Jimmy et al. 2024 and Solomon and George (2019), who reported relatively high literacy levels among catfish farmers. The study also revealed that catfish farmers in both locations had significant experience, with a mean year of experience being 11 years in Nsukka LGA and 12 years in Enugu Metropolis. This level of experience is in line with a study by Enwelu *et al. (*2023) and suggests that the farmers are well-equipped to handle challenges and make informed decisions, which can enhance their productivity and overall success in catfish farming. The study found that the majority of respondents in both Nsukka LGA (63%) and Enugu Metropolis (71.7%) were full-time catfish farmers, indicating that catfish production is their primary source of livelihood. The high percentage of full-time catfish farmers suggests that many households in both locations depend on catfish farming for their livelihood. This highlights the importance of supporting and sustaining the catfish industry.

In terms of scale, most respondents in both locations operated medium-scale catfish farms, with 58.3% in Nsukka LGA and 68.3% in Enugu Metropolis. The dominance of medium-scale catfish farms suggests opportunities for growth and expansion into larger-scale operations, which could increase productivity and income. The income analysis showed that the majority of respondents in both locations earned between ₦61,000 and ₦100,000 per month. However, farmers in Enugu Metropolis had a higher mean monthly income of ₦105,148.02 compared to ₦89,151.75 in Nsukka LGA. The difference in mean monthly income between Nsukka LGA and Enugu Metropolis may be attributed to factors like market access, production costs, or demand. Understanding these factors could help bridge the income gap.

Profitability of catfish production

Tables 2a and 2b present the cost and return analysis of catfish farmers in Nsukka LGA and Enugu metropolis. Results in Table 2a showed that the mean quantity of catfish produced and sold within a production cycle in Nsukka LGA was 805.3, and the average price per kg of catfish was ₦1,580.5. The result further showed that the mean total cost of catfish production was ₦669,526,80, and the mean total revenue was ₦1,272,776.65. Therefore, the results of the gross margin (₦ 662,534.45) and the Net Farm Income (₦603,250.85) analyses indicated that catfish farming was both viable and profitable in Nsukka LGA. The return on investment of the catfish farmers was 1.09, implying that catfish farmers in the Nsukka LGA returned ₦1.09 for every 1.00 Naira invested in the business. This result is in agreement with the findings of Ikechukwu (2023), who found that catfish production was a profitable enterprise with a return on investment of ₦1.11 for every capital invested. However, the result disagrees with the findings of Enimu and Edet (2018) in Delta state, which found that the return on investment was less than ₦1.

The results in Table 2b indicated that the mean quantity of catfish produced and sold within a production cycle in the Enugu metropolis was 912.4, and the average price per kg of catfish was ₦1,620.3. The average total cost of catfish production was ₦678,256.60, and the average total revenue generated was ₦1,478,361.72. Therefore, the results of gross margin (₦861,733.22) and the Net Farm Income (₦800,105.12) analyses in Enugu metropolis showed that catfish farming was a profitable enterprise. The return on investment (ROI) of the catfish farmers was 1.40, implying that catfish farmers in the Enugu metropolis returned ₦1.40 for every 1.00 Naira invested in the business. The result is consistent with the findings of Enwelu et al. (2023), who noted that catfish production was profitable in Anambra State with a return on investment of ₦2.47 for every capital invested. However, it also disagrees with a study by Enimu and Edet (2018), which found a return on investment of 0.48 among catfish farmers in Delta State, Nigeria.

Comparatively, from Tables 2a and 2b, catfish farming was found to be more profitable in the Enugu metropolis when compared to that of Nsukka LGA. Though the cost of feed contributed more than 50% of total expenditure in both locations, the enterprise generated more revenue and consequently more profit and more return on investment in the Enugu metropolis. Therefore, catfish farmers had a higher return on investment (1.40) than those in Nsukka LGA, who had only 1.09 as a return on capital investment. This could be attributed to the fact that the Enugu metropolis had more full-time catfish farmers than Nsukka, as reported in Table 1. Catfish farmers who are full-time operators tend to be more dedicated and committed, and monitor any challenges that can reduce the efficiency of catfish production (Esiobu et al, 2022). Thus, the more time devoted to the enterprise, the higher the propensity to earn more. It can also be linked to the fact that the Enugu metropolis, being the state capital, may have more premium consumers who have more income than those in relatively rural Nsukka LGA.

Constraints faced by Catfish farmers

The constraints militating against the catfish production in Nsukka LGA and the Enugu metropolis are presented in Table 3. The results in the Table showed that the cost of feed (100%) was the major constraint in the catfish production. This is a further confirmation of the high cost of feed reported in Table 1, in which feed accounted for over 50% of the total cost of production in both Nsukka LGA and Enugu metropolis. The result is in agreement with that of Alawode and Ajagbe (2020), who ranked the cost of feed as the most important factor that militates against the level of profitability in cattish production. This suggests that if the cost of feed is reduced drastically, the welfare of the catfish farmers would increase due to increased profit levels.

Table 2a: Cost and Return of Catfish producers in Nsukka LGA per production cycle

	Average Quantity/Cost (₦)	% Share	Price per Kg (₦)	Total (₦)
Revenue				
Catfish	805.3		1,580.5	**1,272,76. 65**
Variable Cost:				
Catfish feeds	340,500.7	50.86		
Drugs/Medications	43, 300.3	6.47		
Liming materials	19,750.5	2.94		
Labour (person-day)	49,600	7.41		
Fingerlings	73, 350.2	10.96		
Transportation	28,440.1	4.25		
Water	115,700	17.30		
Cost of electricity/fuel for pumping water	34,500.5	5.15		
Maintenance/Repairs	21750.4	3.25		
Total Variable Cost (TVC)				**610, 242.20**
Fixed cost (Depreciated Value)				
Pond	30,525.5	4.56		
Pumping machine	12,550.3	1.87		
Weighing Scale	1470.7	0.22		
Water tank	8655.6	1.29		
Bucket and Basins	1198.5	0.18		
Pond net cover	1312.5	0.20		
Net Harvesting	1455.3	0.23		
Ph meter	2114.8	0.32		
Total Fixed Cost (TFC)				**59, 283. 60**
Total Cost (TVC + TFC)				**669, 525. 80**
Gross Margin (TR -TVC)				**662, 534. 45**
Net farm income (TR-TC)				**603, 250. 85**
ROI/RCI GM/TVC				**1.09**
Revenue				
Catfish	912.4		1,620.3	**1,478,361.72**
Variable cost:				
Catfish feeds	355, 090.3	52.35		
Drugs/Medications	45,000.5	6.63		
Liming materials	20, 850.2	3.07		
Labour (person-day)	52,550.1	7.73		
Fingerlings	75,080.4	11.07		
Transportation	30,050	4.43		
Water	120, 500.4	17.77		
Cost of electricity/fuel for pumping water	35,357.2	5.21		
Maintenance/Repairs	23500	3.46		
Total Variable Cost (TVC)				**616, 628. 50**
Fixed cost (Depreciated Value)				
Pond	33,025.3	4.87		
Pumping machine	12,350.1	1.82		
Weighing Scale	1450.4	0.21		
Water tank	8500.6	1.25		
Bucket and Basins	1300	0.19		
Pond net cover	1300.7	0.19		
Net Harvesting	1500.3	0.22		
Ph meter	2200	0.32		
Total Fixed Cost (TFC)				**61, 628.10**
Total Cost (TVC + TFC)				**678, 256. 60**
Gross Margin (TR -TVC)				**861, 733. 22**
Net farm income (TR-TC)				**800, 105. 12**
ROI/RCI GM/TVC				**1.40**

Aside from the cost of feed, the other major challenges facing catfish production in Nsukka LGA, as stated in Table 3, include high interest rate on bank loans (95%), high spread of pests and diseases (95%), lack of quality supply of fingerlings (85%), high cost of water supply (83.3%), high mortality rate (81.7) and inadequate capital (80%). As regards the Enugu metropolis, the major hindrance to catfish production, in addition to the high cost of feed as indicated in Table 3, include high cost of labour (95%), high cost of water supply (93.3), interest rate on bank loan (91.7%), high mortality rate (86.7), high spread of pests and diseases (85%), and lack of quality and supply of fingerlings (85%).

Comparatively, the result further suggests that whereas high interest rate on bank loans (95%) and high spread of pests and diseases (95%) were the second and third most important constraints in Nsukka LGA, the case was not the same with that of Enugu metropolis, in which high cost of labour (95%) and high cost of water supply (93.3%) were ranked as the second and third most important constraints to catfish production. However, catfish producers in both Nsukka and Enugu metropolises ranked the lack of an organised market as the least contributor to inefficiencies in catfish production, with 31.7% and 18.7%, respectively.

Table 3: Constraints Against Catfish Production in Nsukka LGA and Enugu Metropolis

Items	Nsukka		Enugu	
	Frequency	Percentage	Frequency	Percentage
High cost of feed	60	100.0	60	100.0
Inadequate capital	48	80.0	35	58.3
High cost of fingerlings	34	56.7	27	45.0
High cost of water supply	50	83.3	56	93.3
High spread of pests and diseases	27	45.0	21	35.0
High cost of labour	33	55.0	57	95.0
High cost of transportation	47	78.3	55	91.7
Lack of organised market	19	31.7	10	16.7
High spread of pests and diseases	57	95.0	51	85.0
Poorly trained extension Personnel	42	70.0	21	35.0
Lack of Access to credit	44	73.3	38	63.3
High mortality rate	49	81.7	52	86.7
Lack of quality supply of fingerlings	51	85.0	51	85.0
High interest rate on a bank loan	57	95.0	55	91.7
Poor Extension Coverage	28	46.7	32	53.3
Poaching	20	33.3	27	45.0

Multiple Responses*

Conclusions and Recommendations

Catfish farming is a profitable enterprise in both Nsukka LGA and Enugu Metropolis, with higher profitability in Enugu. The industry has significant economic potential, contributing to livelihoods, food security, and employment. However, challenges such as high feed costs, interest rates, labor costs, pests and diseases, poor fingerling quality, and water supply costs hinder its viability. Strategic interventions are necessary to address these challenges and ensure sustainable growth, efficiency, and profitability in catfish farming. Therefore, to enhance catfish farming in Nsukka LGA and Enugu Metropolis, several key measures are recommended. These include promoting cost-effective feed alternatives, improving access to affordable credit, and breeding quality, disease-resistant catfish. Additionally, training farmers to detect pests and diseases early, addressing water scarcity issues, and establishing organized markets with marketing support can help lower costs, increase profitability, and ensure the industry's sustainability.

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Biorationals in the Suppression of Sooty Mold Fungus, *Capnodium* spp. (Camille Montagne) established on the coconut whitefly honeydew

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Abstract

Sooty mould, *Capnodium* spp., a saprophytic fungus from the phylum Ascomycota, produces dark-coloured colonies on plant surfaces smeared with honeydew of coconut whitefly. This study explains eco-friendly biorationals, comprising plant extracts, organic materials, and microbial agents, to control the growth of *Capnodium* spp. Morphological analysis revealed distinct hyphal septation and conical black spores, providing insights into *Capnodium* fungal development. Experiments were conducted using 35 plant extracts, of which 12 showed significant antifungal properties. Inorganic pesticides cannot be sprayed on coconut to control whitefly, as the spray may reach the households, especially waterbodies at households. Extracts of *Acorus calamus* (Sweet flag) exhibited the highest inhibition (98.61% at 50% concentration), followed by *Allium sativum* (Garlic, 84.06%) and *Asparagus racemosus* (Shatavari, 84.72%). In contrast, extracts of vermicompost tea showed no inhibitory effects, while fermented cow urine and distillery spent wash reached 100% inhibition of fungal growth. In microbial agents, *Trichoderma* spp. completely inhibited fungal growth, whereas *Pseudomonas* fluorescens exhibits no effect. The results explained that plant extracts with organic compounds or microbial agents provide solutions as an alternative to chemical fungicides. Combining extracts could provide an eco-friendly and sustainable strategy for managing *Capnodium* spp., reducing crop losses and increasing agricultural sustainability. These findings contribute to the growing body of research supporting biorational approaches as viable, environmentally safe options for fungal management. Field-scale applications are to be tested, and the effect of the biorationals on coconut whitefly also has to be determined.

Keywords- *Acorus calamus, biorational control, Capnodium, Sooty mould, Trichoderma spp.*

Introduction

Sooty mould are saprophytic fungi from Ascomycota, typically with dark-coloured hyphae, resulting in seemingly brown to black colonies on live plants. These types of moulds are frequently connected to whitefly and other producers of honeydew, albeit they can also happen in their absence. Sooty moulds can develop into a pseudoparenchymatous crust, a pellicle, a velutinous growth, or a thin network of hyphae on leaves and smaller twigs. Many sooty mould hyphae have a distinctly mucilaginous outer wall that serves as an adhesive, and quickly absorbs water surely keeping the leaf surface moist for a longer amount of time. Upon bigger branches and trunks the growths are typically stronger and could appear as spongy or lumpy pseudoparenchymatous stromata (Hughes, 2018).

The most frequent genera of fungi that cause sooty mould on garden and landscape plants are *Fumago, Scorias* and *Capnodium*. A few less frequent genera are *Antennariella, Limacinula, Fumiglobus and Aureobasidium.* The kind of presence of sooty mould-causing fungi depends on several factors, including the host, habitat and insect species. A few certain plants or insects are preferred by specific species of sooty mould. Whereas other mould species might grow on a variety of surfaces and make use of honeydew made by several insect species (Ipm 2006). Sooty moulds decrease plants' photosynthetic potential by large mycelial networks, resulting in chlorosis under the mycelia. Hence, sooty moulds hurt crop output and quality (Haituk et al., 2022) especially it over grow on the fruits that cause low market value.

To lessen the negative effects of chemical fungicides on the environment, which can damage non-target organisms, contaminate soil and water, and cause pesticide resistance, eco-friendly management of sooty mould is crucial. Sustainable substitutes that support ecological balance and agricultural sustainability include plant extracts, organic materials, and microbiological agents. They also provide longer-lasting, safer solutions.

The following objectives were developed for the study

i. To conduct a morphological study of the sooty mould fungus colony for a better understanding of its growth characteristics.
ii. To explore eco-friendly alternatives to chemical fungicides for the management of sooty mould.
iii. To assess the antifungal potential of microbial agents in controlling sooty mould fungus.

Materials and methods

These experiments were carried out at the JICA - Plant Protection Laboratory of the Department of Agricultural Biology, Faculty of Agriculture, University of Jaffna.

Isolation and identification of the sooty mould fungus

Isolation and inoculation of sooty mould

Whitefly infested leaves of coconut were collected from a home garden at Iranaimadu, Kilinochchi. The leaves were cut into small pieces and rinsed in distilled water. Then the sample was inoculated into 9 cm Petri dishes containing PDA. Plates were incubated at room temperature (30ºC) for five days. The pure culture of the fungal isolate was maintained in PDA plates and stored in the refrigerator at 4°C for further use. Mycelial growth rate, colour and spore characters of the colony were measured after 3 days of inoculation.

Screening of plant botanicals against sooty mould fungus

For this experiment, thirty-five kinds of plant extracts were tested on sooty mould as a preliminary experiment, however only 09 extracts were found to prominently inhibit mycelial growth higher than 50%.

Selection of plant extracts

Based on the literature research, thirty-five medicinal plants (Table 1)bthat show antifungal properties were identified and selected for *in-vitro* screening against sooty mould fungus.

Table 1: Screening of botanicals to determine their suppressive effect on Sooty mould fungus

Treatment	Botanicals	Family	Plant part used
T1	*Acorus calamus*	Acoraceae	Leaves
T2	*Punica granatum*	Punicaceae	Leaves
T3	*Asparagus racemosus*	Asparagaceae	Rhizome
T4	*Azadirachta indica*	Meliaceae	Leaves
T5	*Aloe barbadensis miller*	Asphodelaceae	Leaves
T6	*Curcuma longa*	Zingiberaceae	Rhizome
T7	*Curcuma aromatica*	Zingiberaceae	Rhizome
T8	*Zingiber officinale*	Zingiberaceae	Rhizome
T9	*Allium sativum*	Amaryllidaceae	Bulb
T10	*Alpinia officinarum*	Zingiberaceae	Rhizome
T11	*Moringa oleifera*	Moringaceae	Leaves
T12	*Ricinus communis*	Euphorbiaceae	Leaves
T13	*Ocimum sanctum*	Lamiaceae	Leaves
T14	*Glycyrhiza glabra*	Liquorice	Root
T15	*Withania somnifera*	Solanaceae	Root
T16`	*Terminalia catappa*	Combretaceae	Leaf
T17	*Tectona grandis*	Lamiaceae	Leaf
T18	*Syzygium cumini*	Myrtaceae	Leaf
T19	*Cynodon dactylon*	Poaceae	Leaf
T20	*Lantana camara*	Verbenaceae	Leaf
T21	*Gliricidia sepium*	Fabaceae	Leaf
T22	*Eucalyptus globulus*	Myrtaceae	Leaf
T23	*Andrographis paniculata*	Acanthaceae	Leaf
T24	*Artemisia vulgaris*	Asteraceae	Leaf
T25	*Ocimum basilicum*	Lamiaceae	Leaf
T26	*Cassia alata*	Fabaceae	Leaf
T27	*Cassia tora*	Fabaceae	Leaf
T28	*Piper nigrum*	Piperaceae	Leaf
T29	*Colocasia esculenta*	Araceae	Tuber
T30	*Chrysopogon zizanioides*	Poaceae	Leaf
T31	*Calotropis gigantea*	Apocynaceae	Leaf
T32	*Bauhinia racemosa*	Fabaceae	Leaf
T33	*Centella asiatica*	Apiaceae	Leaf
T34	*Thespesia populnea*	Malvaceae	Leaf
T35	*Solanum trilobatum*	Solanaceae	Leaf

Preparation of plant extracts

Plant parts which are having higher antifungal properties were collected from different field locations based on the literature (Table 2) and washed with running tap water to remove adhered impurities and rinsed with distilled water, and the surface was sterilised using 3% NaOCl for five mins and thereafter rinsed with distilled water.

The plant parts of the collected plants were sun-dried and made into powder separately using a sterilized grinder. The aqueous extracts were prepared by mixing 10g plant powder with 100 ml of water, if it had the suppression effect then the extracts were prepared into different concentrations to check the suppression effect depending on the concentration of the extracts. The mixture was kept overnight in the shaker to mix well the sample. Then the mixture was filtered through the membrane filter. The supernatant was kept separately. 3.9 g of PDA powder was added with 20 ml of water and sterilized. The autoclaved PDA was mixed with plant extract.



(a) (b)

Plate 1: Procedures for getting plant extract to inhibit the growth of Sooty mould (a): Shaking the powdered plant parts with a shaker (b): centrifuged plant extract

Antifungal activity of plant extracts

The food poisoning technique (Sah et al., 2021) was used as a method to check the inhibitory effect of plant extracts on sooty mould. 15ml of PDA with plant extract was poured into the Petri plate and allowed to solidify. 5mm diameter discs were obtained from a 140-day-old pure culture of sooty mould using a cork borer. The mycelial segment was transferred to plant extracts or organic matter mixed PDA medium. Petri dishes containing PDA without plant extracts were used as a control. The treatments were replicated four times. The inoculated Petri dishes were sealed by parafilm and incubated at room temperature (30ºC). The diameter of growing colonies of the fungus was recorded from 24 hours after inoculation to the time taken for the fungus to fully cover the 9 cm Petri dish.

The percentage growth inhibition (I) was calculated using the formula given below (Sivakumar, 2002)

I%=(C-T) / C

I= Percentage of inhibition of fungus by plant extracts

C=Radial growth in control

T=Radial growth in the treatment

Collection and Preparation of Distillery spent wash, Fermented cow urine and Vermi tea

Distillery Spent Wash (DSW)

One litre of distillery spent wash was obtained from the Araly distillery unit, Jaffna. The collected distillery spent wash was kept in two conical flasks. One is maintained as unsterilized. Another conical flask with distillery spent wash was sterilized with the help of an autoclave at 121° C for 15 minutes. 10%,30%, and 50% of the concentration of the distillery spent wash was taken from sterilized and unsterilized ones, with each concentration having four replicates. and these measured DSW were added to PDA.

Fermented urine

One litre of fermented urine was obtained from the farm of the Faculty of Agriculture, University of Jaffna. The collected fermented cow urine was kept in two conical flasks, from which one was sterilized with an autoclave at 121ºC, 15 psi for 15 mins. The other one was kept as unsterilized. Different concentration (10%, 20%, 50%) of fermented cow urine was taken from sterilized and unsterilized conical flasks. and added into the petri dish with 15ml of sterilized PDA. Each treatments with different concentrations was maintained with four replicates.

Preparation of Vermi tea

Vermicompost was made with bedding material made up of cow dung. Then the vermicompost was sieved and 500 grams of fresh vermicompost was weighed by the electrical balance. That was soaked in one litre of non-chlorinated water and blended thoroughly to create the vermi tea. An aquarium pump was used to aerate the

solution during a 1–2-hour brewing period. Following that, the suspension was filtered through muslin cloth and stored in a sterile glass for use as a treatment to control the sooty mould fungus.

The prepared vermi tea was kept in two conical flasks one was maintained as sterilized with the help of an autoclave. Other is maintained as unsterilized. Different concentration of the vermi tea (10%, 30%,50%) were poured into the 15ml of PDA with four replicates in each concentration.

Effect of different biocontrol agents *Trichoderma* sp. and *Pseudomonas* spp on mycelial growth of sooty mould

Effect of *Trichoderma* spp on Sooty mould

Under *in-vitro* conditions "Dual Culture Technique" was used as described by (Morton and stroube,1955). For the experiment 15ml of sterilized PDA medium were poured aseptically into sterilized petri dishes under laminar flow. 5mm disc of antagonist and test organism were cut from 14 days old culture by sterilized cork-borer and was placed opposite in Petri dishes containing PDA medium.

The disc was placed in a straight line at one centimetre from the corner of the Petri dishes. Potato Dextrose Agar plates inoculated with sooty mould alone were treated as a control. Four replications were maintained. The inoculated Petri dishes were maintained at room temperature and radial growth of *Trichoderma* and sooty mould was recorded for five days from inoculation. The inhibition zone was estimated based on the formula given by Vincent (1947), as the percentage of inhibition

I%=(C-T)/C x 100

I=Inhibition of mycelial growth

C = Growth of pathogen in control plate (cm)

T= Growth of the pathogen in dual cultures (cm)



Plate 2:Pure culture of *Trichoderma*

Effect of *Pseudomonas* sp. on Sooty mould

Suspension of *Pseudomonas* was streaked in the nutrient agar medium. After that the plates were incubated for 24 hours at 30^{O}c.

For dual culture, 20 ml of sterilized PDA medium was poured into the sterilized Petri dishes under the laminar flow condition. The antagonistic bacteria were streaked one cm from the edge of PDA in a 9 cm diameter Petri dish as shown in the Plate 3. After 24 hours of incubation at 28˚C, a 5 mm disc of an actively growing 14 days old culture of sooty mould was inoculated at the centre. Plates inoculated with alone sooty mould were maintained as a control. Plates were incubated for three days at 28°C and the percentage of inhibition of radial growth (PIRG) was recorded using the following formula (Sariah, 1994).

PIRG = (R1-R2)/R1 ×100

R1= Radial growth of sooty mould

R2=interacting with antagonistic bacteria



Plate 3: Pure culture of *Pseudomonas*

Analysis

Statistical Analysis

Each experiments were arranged according to the Complete randomized design (CRD) in two factor factorial and the data were statistically analyzed using SAS package 3.81 (Enterprise edition). Post hoc test was performed using the Duncan Multiple Range Test (DMRT) at 95% of the confidence level**.**

Correlation Analysis

Correlation analysis was performed to understand the relationships between different plant extracts and organic materials based on their inhibitory effects against sooty mould. This analysis aimed to determine if there were any associations between the inhibitory patterns of various treatments, which could suggest common bioactive compounds or similar modes of action.

The Pearson correlation coefficient (r) was calculated to measure the linear relationship between inhibition rates of different treatments at varying concentrations. The value of r ranges from -1 to +1:

- +1 indicates a perfect positive linear relationship.
- -1 indicates a perfect negative linear relationship.
- 0 indicates no linear relationship.

The correlation coefficients were calculated separately for each concentration (10%, 30%, and 50%) to observe how the relationships changed with varying levels of the treatment. A heatmap was created to visualize the correlation matrix, using color gradients to represent the strength and direction of the correlations. Darker shades indicated higher positive or negative correlations, while lighter shades indicated weaker correlations. Correlations with p-values less than 0.05 were considered statistically significant, indicating that the observed relationships were not due to random chance.

Based on these correlation patterns, treatments with r values close to +1 were identified as having similar inhibitory patterns, while treatments with low or negative correlations suggested distinct inhibitory properties.

Results and Discussion

This chapter describes the findings of the experiments conducted to determine the objectives proposed to find a solution and discusses the literature obtained from the published research papers and sources which are documented in Chapter 3.

Colony morphological characters of sooty mould culture

Sooty mould grown in PDA is shown in Plate 1. It had a full growth in a 9cm petridish within 3 days, specific growth rate of this fungus is not reported in any reports because the growth rate may be affected by environmental conditions (Smith et al., 1980). It first created white colour mycelium but after 7 days it turned into black colour. The texture of the colonies was primarily in velvety but some of the areas displayed a powdery appearance. The surface of the colonies was smooth with slight radial grooves visible under magnification. Circular-shaped colonies were observed but after one-week irregular edges were also observed in the colony similar report byAguirre-hudson et al. (2014). After 3 days of incubation at 30ºC, 9cm of growth is observed. The pigmentation was higher in the center compared to the periphery of the colony. Spore production was started after 10 days of inoculation. The spores were observed as scattered small black dots on the upper surface of the colony.

The morphological characters were also observed in the microscope by doing the hanging drop technique. The septation was observed in the hyphae of the fungus. The spores was in black with a conical shape, these microscopic characters are alinged with (Hughes 2018) observed characters.




(a) (b)

Plate 4 : Colony of Sooty mould (a): In 3 days after inoculation (b): In ten days after Inoculation

Evaluation of plant extracts with different concentrations against Sooty mould fungus

Table 2: Inhibition percentage of different plant extracts at different concentrations against sooty mould fungus (*Capnodium* spp) under *in vitro* condition

Plant extract	Inhibition percentage (%)		
	10%	30%	50%
1. Sweet flag	79.69±0.73^{a}	83.14±0.77^{a}	98.61±1.67^{b}
2. Khus	0^{d}	46.08±0.36^{c}	64.86±2.37^{a}
3. Pepper	0^{d}	0^{d}	4.38±1.35^{d}
4. Turmeric	40.22±2.98^{c}	53.39±2.69^{e}	75.83±2.62^{a}
5. Wild turmeric	41.86±2.9^{c}	52.92±2.28^{e}	81.25±0.52^{a}
6. Asparagus	30.86±2.25^{c}	52.92±2.82^{e}	84.72±1.66^{a}
7. Lesser galangal	0^{d}	22.61^{f}	42.22^{c}
8. Garlic	45.83±6.11c	65.47±1.39^{g}	84.06±1.75^{a}
9. Indian winter cherry	0^{d}	50.83±4.19^{e}	63.97±3.29^{g}
10. sickle senna	28.81±3.27^{c}	32.64±1.38^{c}	43.89±1.92^{c}
11. Gliricidia	0^{d}	16.75±2.04^{f}	51.94±2.62^{e}
12 .Mugwort	3.75±3.18^{d}	42.22±1.92^{c}	52.22±2.46^{e}

Values having the same letters in a column are not significantly different according to DMRT at 0.05 α

The inhibition percentage of different plant extracts with different concentrations is shown in Table 3 From the 35-plant extracts only 12 plant extracts showed inhibitory effects against the Sooty mould fungus, those 12 plant extracts performance are described in Table 3. From twelve plants, only nine plant extracts shown an inhibitory percentage of more than 50%. The highest inhibition (98.61±1.66%) was observed in sweet flag plant extract .at the concentration of 50% as of inhibition. And 10% concentration of this plant extract show 79.69±0.733% inhibition and 30% of this plant extract shows 83.14±0.766 % inhibition. These results revealed that chemical compounds which are present in the sweet flag plant have high antifungal properties against the sooty mould fungus compared to other tested plant extracts. Next to the sweet flag significant inhibition percentages found in the asparagus (84.72%) and garlic (84.06%). turmeric (75.83%) wild turmeric (81.25%), turmeric (75.83%).

Other than this plant extracts like *Colocasia*, neem, liquorice, country almond, castor, Bermuda grass, *Centella*, ginger, teak, pomegranate, eucalyptus, bidi leaf tree, milkweed, jamun, moringa, holy basil is didn't contribute to the suppression of the sooty mould. Which means there is no significance in these treatments. So chemical compounds which are present in these plants are not suitable for the control of sooty mould or the concentration is may not be enough for the growth of the inhibition of the growth of the fungus. So the further study need to optimize the concentrations wants to see the efficacy of the chemical compounds to suppress the fungus.the chemical compounds that show antifungal properties against sooty mould fungus depend on the concentrations.

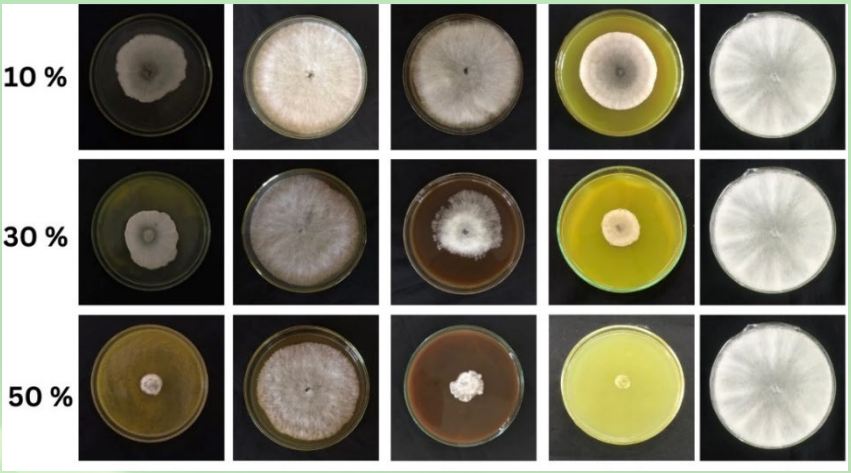
When the concentration increases in higher percentages their inhibitory property also will increase in higher levels, which is also reported by (Dellavalle et al. 2011). For example, the wild turmeric which shows 41.86% as its

inhibition percentage, changes to 65.47% when the concentration is increased from 10% to 30% and then reaches a higher inhibition percentage of 81.25% at 50% concentration. Indian winter cherry had 0% inhibition in 10% concentration of the plant extract suddenly reaches the inhibition percentage of 50.83% when the concentration at 30%. The results revealed that inhibition efficacy of the plant extract correlate with the plant extract concentration.



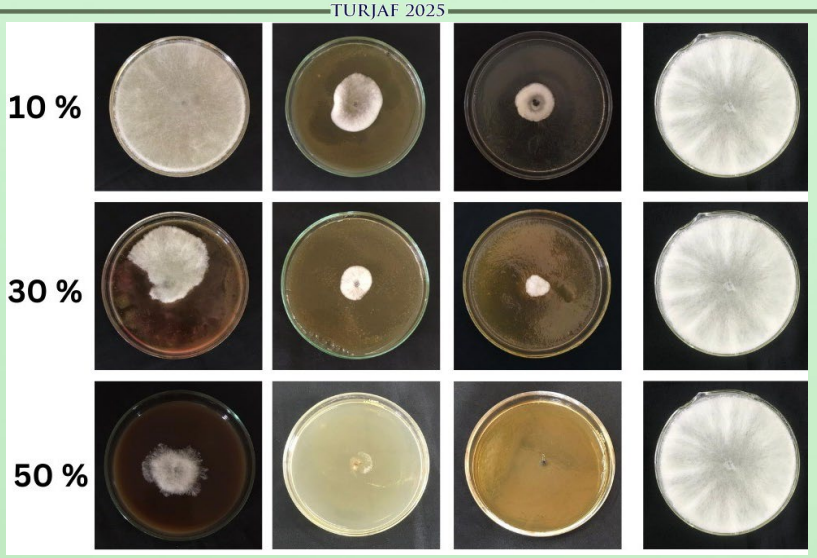
(a) (b) (c) (d) (e)

Plate 5: Comparison of growth of different plant extracts with control (a): Indian winter cherry, (b): Asparagus, (c): Lesser galangal, (d): Garlic, (e): Control



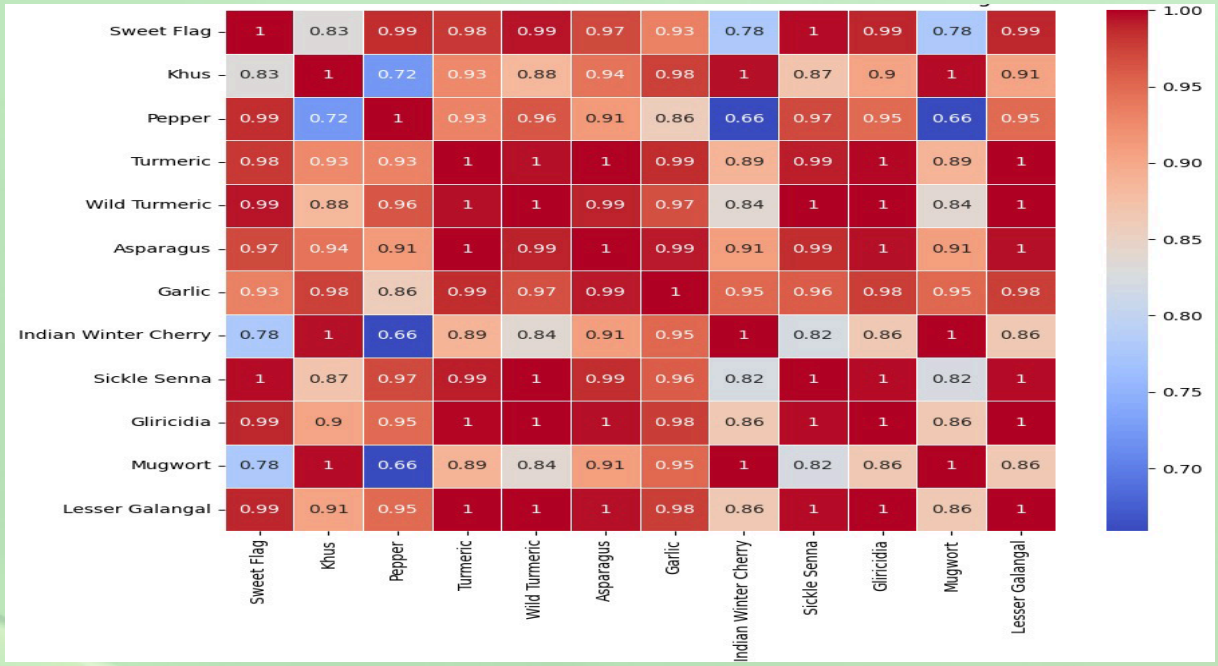
(a) (b) (c) (d) (e)

Plate 6: Comparison of growth of Sooty mould in different plant extract and in control(a): Wild turmeric (b): Pepper (c): Mugwort (d): Turmeric (e): Control



(a) (b) (c) (d)

Plate 7: Comparison of growth of Sooty mould in different plant extract and in control (a):Khus (b):Sickle senna (c) Sweet flag (d):Control



Correlation Between Plant Extract Based on Inhibition Percentage

The primary purpose of conducting correlation analysis on the antifungal activity of various plant extracts against sooty mould is to identify potential synergistic effects and relationships among the extracts. By examining correlation patterns, researchers can determine whether certain plant extracts share similar inhibitory properties, which may indicate the presence of complementary or overlapping bioactive compounds.

This analysis helps in understanding the interactions between different extracts and can provide insights into developing effective botanical mixtures with enhanced antifungal activity. Additionally, the correlation analysis can reveal unique properties of specific plant extracts that show weaker or distinct inhibition patterns, suggesting that these extracts might require different concentrations or combinations for optimal effectiveness. The findings from such an analysis are essential for guiding future research on optimizing the use of plant-based bio-fungicides in eco-friendly agricultural practices.

The idea of utilizing correlation analysis in evaluating the effects of plant extracts is supported by the research conducted by Dellavalle et al. (2011) and Singh et al. (2023). Studies have shown that synergy among bioactive compounds in plant extracts can significantly enhance their antifungal properties compared to their individual effects. The concept of synergistic effects and correlation analysis in plant extracts has been previously reviewed in other phytochemical studies that aim to understand plant–fungus interactions and to improve the efficacy of natural fungicide (Díaz Dellavalle et al. 2011);(Singh et al. 2023)

The high correlation coefficients (0.99 or 1) observed between Sweet Flag, Turmeric, Wild Turmeric, Asparagus, and Garlic indicate that these extracts exhibit highly similar inhibitory patterns against sooty mould. However, it is important to note that similar inhibition percentages do not necessarily imply similar chemical compositions or modes of action. For instance, different sets of bioactive compounds could produce comparable inhibition results due to varying mechanisms, such as disrupting cell walls or inhibiting fungal enzyme activity.

However, based on the work of Dellavalle et al. (2011) it can be intuitively expected that the bioactive chemicals contributing to the inhibitory potential of these various extracts could be complementary or overlapping. There aren't many relationships between Pepper and Indian Winter Cherry and other plant extracts. Pepper exhibits poorer correlations than the other extracts, particularly with Khus (0.72) and Indian Winter Cherry (0.66). This could mean that Pepper has a distinct mode of action or less potent inhibition than the other extracts. Indian Winter Cherry also correlates less with others, suggesting unique properties of its inhibitory action. These results suggest that these extracts might not be as effective overall or that they might require other chemicals or amounts to act as an inhibitor.

While Khus's correlations with most extracts are moderate (0.72 with Pepper, 0.88 with Wild Turmeric, and 0.87 with Sickle Senna), which suggests that its inhibition potential is not as strong as extracts like Sweet Flag, Turmeric, or Garlic, it still shows notable inhibition, particularly in specific concentrations. Gliricidia and Mugwort show moderate correlations (0.9–0.95) with most extracts, indicating that their overall inhibitory potential is slightly lower than that of other extracts like Garlic and Sickle Senna, with slightly weaker inhibition potential overall. When compared to highly correlated plant extracts like Sweet Flag and Turmeric, Pepper and Indian Winter Cherry stand out in terms of their correlation patterns. These outliers show that Pepper and Indian Winter Cherry may have unique inhibitory profiles and may not follow the same trends as the other more correlated extracts.

To make definitive conclusions regarding the similarity of bioactive chemicals, further phytochemical analysis and studies comparing the chemical profiles of these extracts would be necessary. Without such evidence, it is not possible to conclusively state that these extracts contain overlapping or complementary compounds. Thus, while the inhibition patterns observed are noteworthy, further research and references are required to confirm any claims regarding chemical similarity or mode of action.

Evaluation of inhibition of organic materials in the growth of sooty mould fungus.

Table 3: Inhibition percentage of organic materials at different concentrations against sooty mould under *in vitro* condition

Organic material	**Inhibition percentage**		
	10%	**30%**	**50%**
Distillery spent wash (Sterilized)	100[a]	100[a]	100[a]
Distillery spent wash (Unsterilized)	100[a]	100[a]	100[a]
Fermented urine (Sterilized)	100[a]	100[a]	100[a]
Fermented urine (Unsterilized)	100[a]	100[a]	100[a]
Vermi tea (Sterilized)	0[b]	0[b]	0[b]
Vermi tea (Unsterilized)	0[b]	0[b]	0[b]

All the values in each column having the same are not significantly different according to DMRT at 0.05.

Table 4: Evaluation of different parameters of fermented cow urine, distillery spent wash, vermi tea

Organic material	**TDS (mg/l)**	**PH**
Distillery spent wash (Sterilized)	1741	6.4
Distillery spent wash (Unsterilized)	1734	6.2
Fermented cow urine (Sterilized)	1600	5.8
Fermented cow urine (Unsterilized)	1587	5.6
Vermi tea (sterilized)	500	7.0
Vermi tea (unsterilized)	400	6.8

Fermented cow urine both sterilized and unsterilized was shown a 100% inhibition rate against the sooty mould fungus, it indicates strong antifungal properties. This effect may be due to the presence of bioactive compounds like phenols, ammonia, and other antimicrobial compounds which are present in the cow urine and also nutrient in a rich condition due to higher TDS (Singh Rawat et al. 2020).

Distillery spent wash also contribute to the complete inhibition of the fungus. This also due to the high organic compound content (higher TDS) and also presence of organic acids and alcohols that possess antifungal property (Kaushik et al. 2018). In contrast vermi tea's inhibition percentage is 0. It may be due to the absence of specific chemical compound/ nutrient which is required to inhibit the sooty mould fungus. The results suggest that the antifungal activity is influenced by both the chemical composition and the pH of the organic materials.

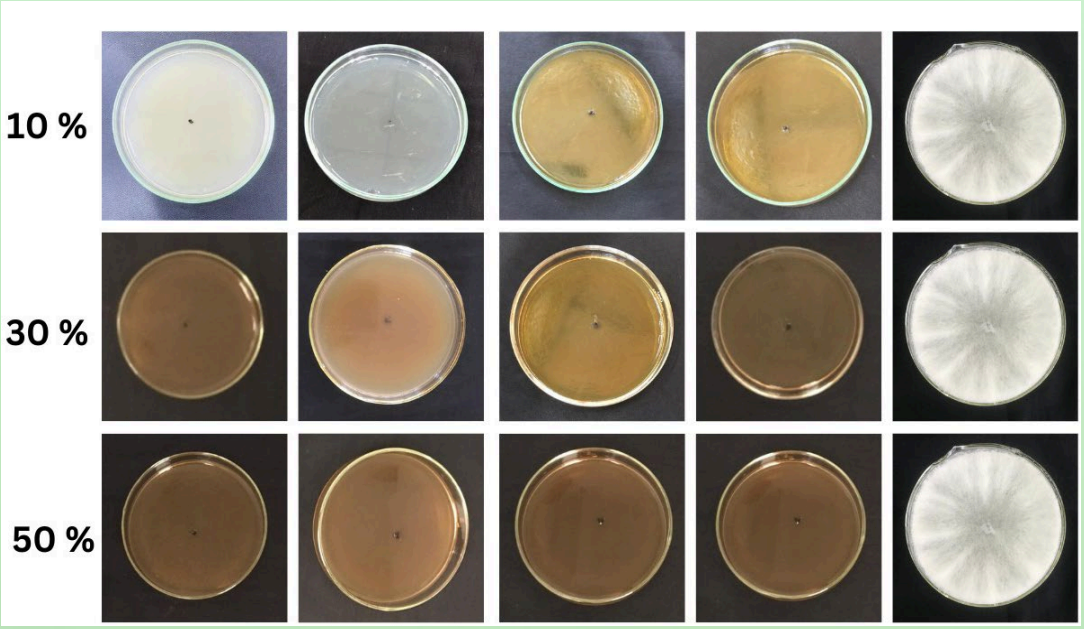


Plate 8: Comparison of growth of sooty mould in different plant extract and in control (a) Distillery spent wash(sterilized) (b) Distillery spent wash (unsterilized) (c) Fermented cow urine (Sterilized) (d) Fermented cow urine (unsterilized) (e) Control

These images indicates in plate 7 ,that there is no growth of Sooty mould in the treatments. Zero growth rate is observed.

Figure *1*:Inhibition percentage of Sooty mould in organic material at different concentration

Figure 3 shows the inhibition of Sooty mould using the fermented cow urine, distillery spent wash with different concentration of inhibition but the inhibition percentage remain as 100% even though the concentration is reduced.

Evaluation of Antifungal activity of *Trichoderma* species against Sooty mould fungus

Table *5*:Day by day growth of *Trichoderma* against Sooty mould

Organism	**Growth (cm)**				
	1st DAC	**2nd DAC**	**3rd DAC**	**4th DAC**	**5th DAC**
Trichoderma sp	1.5	2.6	3	4.7	9
Sooty mould	2.5	5.2	6	4.4	0

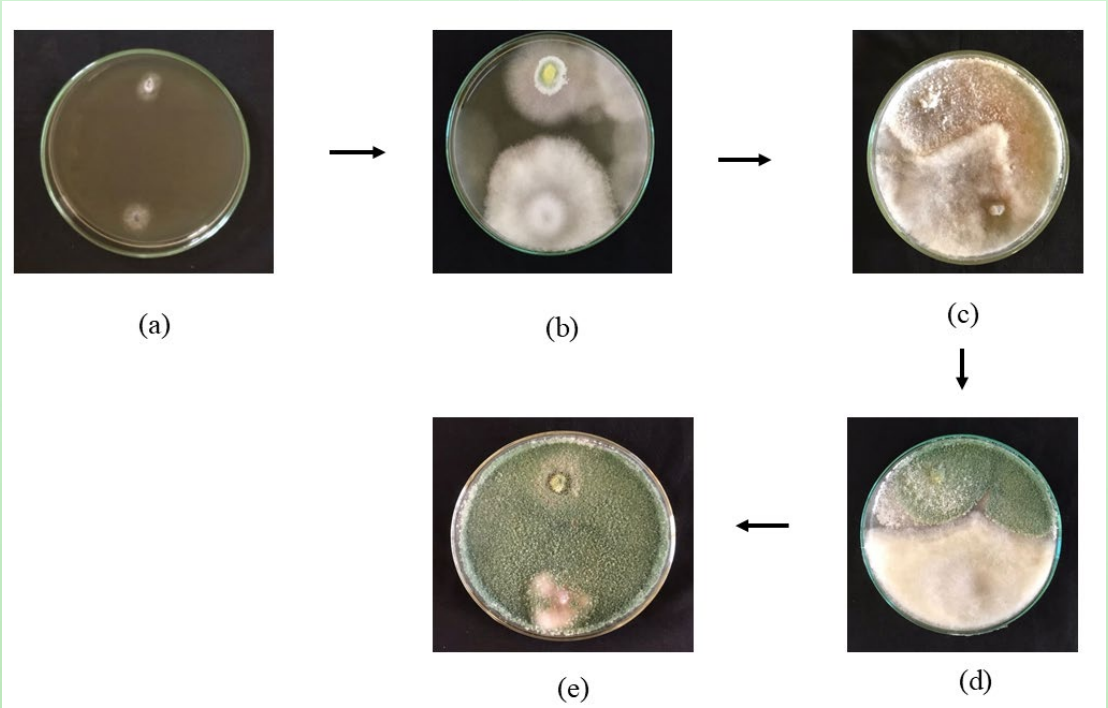


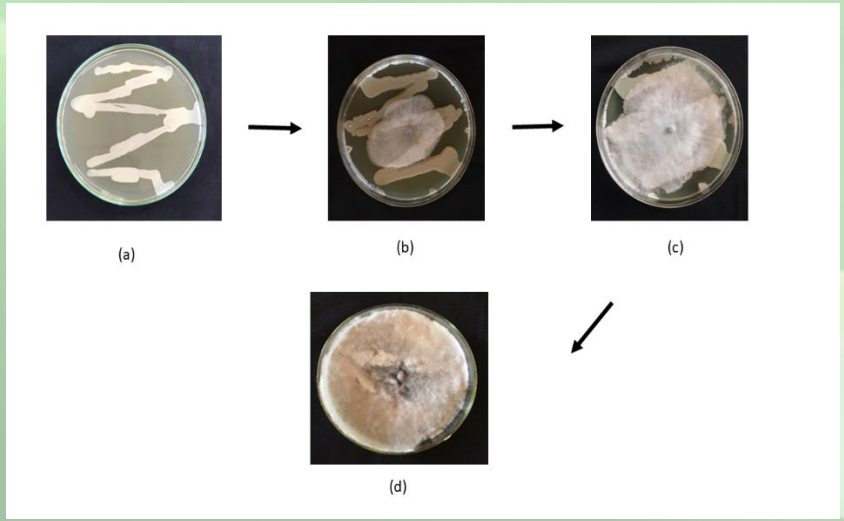
Plate 9: Gradual growth of *Trichoderma* in Dual culture with Sooty mould (a) 1 DAC (b) 2 DAC (c) 3 DAC (d) 4 DAC (e) 5 DAC

The colony of *Trichoderma* and Sooty mould grow normally without any interruption until the second day after inoculation. The third day Sooty mould mycelial growth is slightly inhibited by the *Trichoderma.* Because normally the growth of Sooty mould will reach 9cm after 3 days of incubation. but the mycelium was only reached 6cm and other spaces of the Petri dish was encroached by *Trichoderma*
Gradually *Trichoderma* was spread to the petri dish fully and suppress the sooty mould. Growth of Sooty mould in control is 9cm and the growth of Sooty mould in dual culture in 0. So the results revealed that the inhibition percentage of the *Trichoderma* to Sooty mould fungus is calculated as 100%. So the *Trichoderma* fully control the sooty mould. Sooty mould have the antifungal activity against many fungus through their mechanisms such as mycoparasitism, competition and production of antifungal compounds (Mukhopadhyay and Kumar 2020).

Evaluation of the antifungal activity of *Pseudomonas* species against sooty mould fungus

Table *6*: Day-by-day growth of Sooty mould in control and in *Pseudomonas* inoculated culture plate

	Colony diameter cm		
	1st DAC	**2nd DAC**	**3rd DAC**
Dual culture	2.7	5.2	9
Pure culture	2.9	5.8	9



Sooty mould culture was grown normally like the control one without any interruption in the dual culture . Within three days the fungus was grown fully to 9cm in diameter and covered the petri dish fully.There is no suppression effect of *Pseudomonas* for sooty mould fungus. So radial growth of the pathogen in control and the radial growth of the pathogen in dual culture were equal of 9 cm (0% inhibition).0. *Pseudomonas* inhibit many fungus species (Goswami et al. 2015). Due to the superficial growth and environmental conditions may be unsuitable for controlling of the sooty mould with *Pseudomonas* bacteria.

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ID: 748

Comparative Study of Biological Control Agents against Common Bacterial Blight Disease in Dry Beans

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Abstract

Bean (*Phaseolus vulgaris*) is widely grown crops with high nutritional and commercial value that are staples on several continents. However, common bacterial blight (CBB), which is caused by *Xanthomonas axonopodis* pv. *phaseoli* is one of the most critical seed-borne destructive diseases of beans, having a major adverse effect on dry bean production, resulting in yield and quality losses. This study was conducted to examine the efficacy of biological control agents and a copper-based treatment in managing CBB under *in vitro* and *in planta* controlled conditions. In this study, various bacterial treatments, including *Bacillus subtilis* (Bs), *Pseudomonas fluorescens* (Ps), and a mixed treatment (Bs+Pf), were tested and compared to copper hydroxide (Ch) and control treatments. Disease incidence, disease severity index, and plant growth parameters such as plant height, number of leaves, root length, and weight, were evaluated to determine the effectiveness of each treatment. According to the results, there was a significant difference among treatments ($p<0,01$), as Bs demonstrated efficient *in vitro* inhibition (34.00 mm) and achieved 71% disease control in the *in planta* study. In the *in planta* study, the mixed treatment of Bs+Pf was the most significant among all treatments, reducing CBB to 10.33 and controlling the disease by 83.94%. Additionally, it inhibited the pathogen *in vitro* with a zone of inhibition measuring 23.66 mm. In comparison, Pf and the Ch control achieved 58.00% and 65.80% disease control, respectively. The mixed treatment yielded the greatest plant height (71.33 cm), while Bs produced the highest number of leaves (69.00) and the longest root length (19.00 cm). These findings underscore that integrating beneficial bacterial strains, particularly the combination of Bs and Pf, has strong potential as an eco-friendly alternative to pesticides for managing CBB in dry beans.

Keywords: *Xanthomonas axonopodis pv. phaseoli, biological control, Bacillus, Pseudomonas, bean*

Kuru Fasulyelerde Yaygın Bakteriyel Yanıklık Hastalığına Karşı Biyolojik Kontrol Ajanlarının Karşılaştırmalı Çalışması

Özet

Fasulye (*Phaseolus vulgaris*), birçok kıtada temel gıda maddesi olan, yüksek besin ve ticari değere sahip, yaygın olarak yetiştirilen bir üründür. Bununla birlikte, *Xanthomonas axonopodis* pv. *phaseoli*'nin neden olduğu yaygın bakteriyel yanıklık (CBB), kuru fasulye üretimi üzerinde büyük olumsuz etkiye sahip olan ve verim ve kalite kayıplarına yol açan, fasulyelerin en kritik tohum kaynaklı tahripkar hastalıklarından biridir. Bu çalışma, biyolojik kontrol ajanlarının ve bakır bazlı bir uygulamanın, *in vitro* ve *in planta* kontrollü koşullar altında CBB'yi yönetmedeki etkinliğini incelemek için yürütülmüştür. Bu çalışmada, *Bacillus subtilis* (Bs), *Pseudomonas fluorescens* (Ps) ve karışım bir uygulama (Bs+Pf) dahil olmak üzere çeşitli bakteriyel uygulamalar test edilmiş ve bakır hidroksit (Ch) ve kontrol uygulamalarıyla karşılaştırılmıştır. Her bir uygulamanın etkinliğini belirlemek için hastalık insidansı, hastalık şiddeti endeksi ve bitki boyu, yaprak sayısı, kök uzunluğu ve ağırlığı gibi bitki büyüme parametreleri değerlendirilmiştir. Sonuçlara göre, uygulamalar arasında önemli bir fark ($p<0,01$) bulunmuş, Bs *in vitro* da önemli inhibisyon göstermiş (34,00 mm) ve *in planta* çalışmada %71 hastalık kontrolü sağlamıştır. *In planta* çalışmasındada, Bs+Pf'nin uygulaması tüm uygulamalar arasında en önemli olanıydı, CBB hastalık şiddetini 10,33'e düşürerek ve hastalığı %83,94 oranında kontrol etmiştir. Karşılaştırma olarak, Pf ve Ch kontrolü sırasıyla %58,00 ve %65,80 hastalık kontrolü sağlamıştır. Karışım uygulama en uzun bitki boyunu (71,33 cm), Bs ise en fazla yaprak sayısını (69,00) ve en uzun kök uzunluğunu (19,00 cm) sağlamıştır. Bu bulgular, özellikle Bs ve Pf kombinasyonu olmak üzere faydalı bakteri türlerinin entegre edilmesinin, kuru fasulyelerde CBB'yi yönetmek için pestisitlere çevre dostu bir alternatif olarak güçlü bir potansiyele sahip olduğunu vurgulamaktadır.

Anahtar kelimeler: *Xanthomonas axonopodis pv. phaseoli, biyolojik kontrol, Bacillus, Pseudomonas, fasulye*

ID: 750

Insights into the Apple Tree Microbiome: Determination of Pathogenic and Beneficial Bacteria

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Abstract

In this study, the phyllospheric and rhizospheric microbiota of apple trees (***Malus domestica*** L.), one of the most significant crops in pome fruit cultivation, were investigated using a standardized sampling methodology. Genomic DNA was extracted from the collected samples utilizing the F-Spin Bacterial Fecal/Soil DNA Isolation Kit. Molecular identification was performed through the amplification of the V4 hypervariable region of the 16S rRNA gene using the primer set 533F-805R. In addition to molecular analyses, soil and leaf samples were cultured under laboratory conditions at the Molecular Plant Bacteriology Laboratory, Department of Plant Protection, Selcuk University, where biochemical characterization and pathogenicity assessments were conducted. According to the findings, the bacterial communities exhibited varying compositions across different orchards, with members of the phyla ***Proteobacteria***, ***Bacteroidetes***, ***Actinobacteria***, and ***Firmicutes*** being predominant. Importantly, several key apple pathogens were identified, including ***Erwinia amylovora***, ***Pseudomonas syringae*** pv. ***syringae***, and ***Rhizobium radiobacter***. The results suggest that the interactions between pathogenic and beneficial bacterial agents within the apple microbiota, under natural environmental conditions, differ across regions and climatic zones. These insights are anticipated to provide a foundational basis for the development of novel biological control strategies.

Keywords: *apple, biological composition, soil, foliar, identification*

Elma Mikrobiyomuna Bakış: Patojenik ve Faydalı Bakterilerin Belirlenmesi

Özet

Bu çalışmada, yumuşak çekirdekli meyveciliğinin en önemli ürünlerinden biri olan elma (*Malus domestica* L.) ağaçlarından, standart örnekleme metodu kullanılarak filosferik ve rizosferik mikrobiyotasının incelenmesi amaçlanmıştır. Laboratuvara ulaşan örneklerden genomik DNA, F-Spin Bacterial Fecal/Soil DNA izolasyon kiti kullanılarak elde edilmiş moleküler tanılama 16S rRNA genine ait V4 bölgesi 533F-805R primer dizileri ile amplifiye edilmiştir. Toprak ve yaprak örnekleri aynı zamanda Selçuk Üniversitesi Bitki Koruma Bölümü Moleküler Bitki Bakteriyoloji Laboratuarında kültüre alınmış, biyokimyasal tanıları ve patolojik özellikleri belirlenmiştir. Elde edilen bulgulara göre; farklı bahçelerde farklı oranlarda Proteobacteria, Bacteroidetes, Actinobacteria ve Firmicutes'in hakim olduğu bakteriyel yapıda, başta *Erwinia amylovora*, *Pseudomonas syringae* pv. *syringae*, *Rhizobium radiobacter* olmak üzere önemli elma patojenleri de belirlenmiştir. Çalışma kapsamında, elma mikrobiyatasında belirlenen bakteriyel patojen ve faydalı bakteriyel etmenlerin doğal koşullarda etkileşimleri farklı iller ve iklimsel koşullar düzeyinde belirlenirken yeni biyolojik mücadele olanaklarının araştırılmasına da temel olacak sonuçlara ulaşıldığı düşünülmektedir.

Anahtar kelimeler: *elma, biyolojik kompozisyon, toprak, yeşil aksam, teşhis*

ID: 752

Impact of foliar applied rutin on some physiological and yield parameters of lettuce under different saline irrigation water stress

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Abstract

Salinity is one of the greatest threats to global food security and is recognized as the largest source of abiotic stress in agricultural production. Rutin is a natural flavonoid found in advanced plants and has a stimulatory effect on the defense mechanism against abiotic and biotic stresses. This study conducted a pot experiment in a climate chamber to determine the effect of rutin flavonoid in lettuce plants under salinity stress. In the study, 4 saline water doses (0, 1.2, 2.4, and 3.6 dS m^{-1}) and control (Non-rutin) and 1 mmol L-1 rutin treatment (Rutin) were applied. Leaf dry matter content, electrolyte leakage, and relative water content were analyzed. As a result of the study, it was determined that increasing saline irrigation stress significantly decreased dry matter and leaf relative water content and increased leaf electrolyte leakage. On the contrary, rutin application alleviated the stress by significantly reducing electrolyte leakage. Based on the study's results, it is concluded that rutin application can be used as a stress mitigant for the sustainable commercial cultivation of lettuce.

Key Words: *Electrolyte leakage, Relative water content, Rutin, Salinity stress*

Introduction

Lettuce *(Lactuca sativa* L.) is one of the most widely consumed leafy vegetables and has significant economic value, especially in the restaurant and food processing sectors (Kim et al., 2016). It is becoming increasingly popular, especially among younger generations worldwide, where it is consumed as a significant ingredient in ready-to-eat meals. However, like other vegetable crops, lettuce production faces significant challenges due to salinity stress (Cakmakci et al., 2022; Gruda et al., 2024). Increasing salinity levels in soil and irrigation water worldwide significantly threaten agricultural production (Sahin et al., 2016). Increasing soil salinity, global warming, erosion of minerals, rising sea levels, and over-fertilization in agriculture contribute to the salinity problem. Also, decreasing arable land and agricultural productivity due to climate change threatens millions of people with poverty and under-nourishment (Pradhan et al., 2017).

In recent years, elicitors against stress factors have been widely recognized as a tested technological tool to improve quality and yield in agricultural production (Kazemi, 2014; Javanmardi and Akbari, 2016). Elicitors or biostimulants can be defined as substances that stimulate the defense mechanism in any plant, triggering or enhancing the biosynthesis of secondary compounds of nutraceutical value (Baenas et al., 2014; Gorni et al., 2021). Furthermore, biostimulants can improve plant growth by stimulating different physiological processes (Gorni et al., 2021). This comprehensive definition of stimulants includes both pathogen-derived substances (exogenous stimulants) and compounds released from plants by the action of the pathogen (endogenous stimulants) (Angelova et al, 2006). Rutin is an allelochemical of the flavonoid family, which is considered to be a plant-produced signaling molecule naturally found in developed plants, possessing antioxidant properties and stimulating the defense mechanism against biotic and abiotic stresses (Merewitz and Liu, 2019; Gorni et al., 2022). Rutin application promoted plant growth by reducing oxidative damage in quinoa and broad bean plants (Ismail et al., 2015). Rutin promoted plant growth by reducing oxidative damage in quinoa and broad bean plants (Ismail et al., 2015). Another study reported that rutin synthesis in grass promoted plant growth under heat stress and protected against stress (Merewitz and Liu, 2019). In addition, rutin is also known to play an important role in various physiological processes such as photosynthetic activity, energy transfer, UV protection, antibacterial activity, growth, and development in plants (Singh et al., 2017; Merewitz and Liu, 2019).

Based on the literature, this study hypothesized that rutin-treated plants under salinity stress conditions would increase plant growth and development and alleviate salinity stress damage. To test these hypotheses, the study aimed to determine the dry matter content, membrane damage index, and leaf proportional water content of rutin application under salinity stress.

Materials and Methods

Material

The experiment was carried out in the climate chamber of the Department of Horticulture, Faculty of Agriculture, Van Yüzüncü Yıl University. The experiment used standard lettuce (Lactuca sativa) as plant material. The temperature and relative humidity inside the climate chamber were monitored using an automatic weather station

(HOBO, Campbell Scientific INC., USA). The average daily temperature was 22±2 °C, and the relative humidity was 65±5 %. Lettuce seeds were sown in a randomised experimental design with three replications, producing 24 pots with four plants in each replicate.

Rutin and salinity treatments

In the study, 2 rutin (R) applications (R0: control; R1: 1 mmol L-1) were applied. Rutin in powder formulation was applied by foliar spray for three consecutive days (20 days after seed planting). For Rutin solution, Rutin was weighed on a precision balance, dissolved in methanol (10 mL), and finally added to 1000 mL of 0.02% Tween solution prepared with distilled water. Leaves of control plants were sprayed with water only.

For salinity stress, NaCl was applied as a saline water source. Threshold values and yield loss levels of lettuce plants were taken into consideration while determining salt doses (Ayers and Westcot, 1976; 1985; 1989). In the study, water with 4 different irrigation water salinities (Sw-0: 0.60 dS m^{-1}, control; Sw-1.2: 1.2 dS m^{-1}; Sw-2.4: 2.4 dS m^{-1}; Sw-3.6: 3.6 dS m^{-1}) were used. The salinity of the irrigation water was prepared and applied before each irrigation. Salinity applications started when the plants reached 4-5 true leaf stage.

Dry matter ratio (DM)

Lettuce leaves were separated from the stems, weighed to obtain fresh weight, and recorded. Subsequently, the same leaf samples were dried in an oven at 65°C for 48 h, weighed again, and obtained. The dry weight ratio to fresh weight was calculated to determine the plants' dry matter content (DM).

Electrolyte leakage (EL)

Electrolyte leakage was calculated by measuring the outflow of electrolyte from leaf cells (Shi et al., 2006). Samples taken as discs (10 mm diameter) from each plant leaf before harvesting were placed in 50 ml tubes containing 30 ml de-ionised water for 24 hours at room temperature, and then the electrical conductivity of the water in the tube was measured, and the EC1 value was obtained. Then, the tubes containing the sample were kept in a water bath at 95 °C for 20 minutes, cooled to room temperature, and the electrical conductivity of the water in the tube was measured again, and the EC2 value was obtained. Using the EC1 and EC2 values found, the electrolyte leakage (MZI) will be determined with the help of the following Equation.

$$EL = (EC1 / EC2) \times 100$$

Leaf relative water content (LRWC)

To determine leaf relative water content (LRWC), fresh weights (LFW) of leaf samples taken 10 mm in diameter before harvesting were weighed on a precision balance and recorded as LFW. Leaf turgor weights (LTW) were recorded by soaking the same samples in distilled water for 4 hours. Leaf dry weights (LDW) were determined by drying and weighing the samples in an oven at 65°C for about 48 hours. LRWC was calculated from the obtained weights using the following equation (Smart and Barss 1973, Ors et al., 2021):

$$LRWC\ (\%) = 100 \times (LFW - LDW)/(LTW - LDW)$$

Statical Analaysis

All multivariate analyses were performed with IBM SPSS Statistics version 21.0. One-way analysis of variance (One-way ANOVA) was performed for data comparison, and Duncan's multiple comparison test (at 0.05 % probability) was used to determine the differences between groups. All values were presented as mean ± standard deviation (SD).

Results and Discussion

Rutin treatments caused an increase in lettuce leaf dry matter ratio, but this effect was not found to be significant statistically (Fig. 1). The rutin increased dry matter ratio by 0.5% compared to control plants. On the other hand, the salt stress affected DM negatively, but these differences were not statistically significant. Also, 3.6 dS m-1 of saline water application decreased the dry matter ratio by 2%. No significant interaction was found between rutin and salinity treatments. The highest DM (93.4%) was found in control SW-0 and rutin-treated plants. Biostimulants play important roles in plant growth and development, and these properties can be associated with improving photosynthesis and carbohydrate accumulation in plants (Siddiqui et al., 2020; Gorni et al., 2020). An increase in leaf dry matter content was observed in lettuce plants treated with a 1 mmol L-1 dose of rutin. In a previous study, rutin application increased growth and development parameters such as leaf number, leaf area, fruit, and shoot weight in tomato plants (Gorni et al., 2022). Another study reported that exogenous application of rutin decreased total reactive oxygen species and improved the growth of rice plants (Singh et al., 2017). These responses may be related to increased photosynthetic activity (Hussain and Reigosa, 2016; Singh et al., 2017) and interaction with hormones (Hussain and Reigosa, 2014) and may be associated with increased dry matter in lettuce plants.

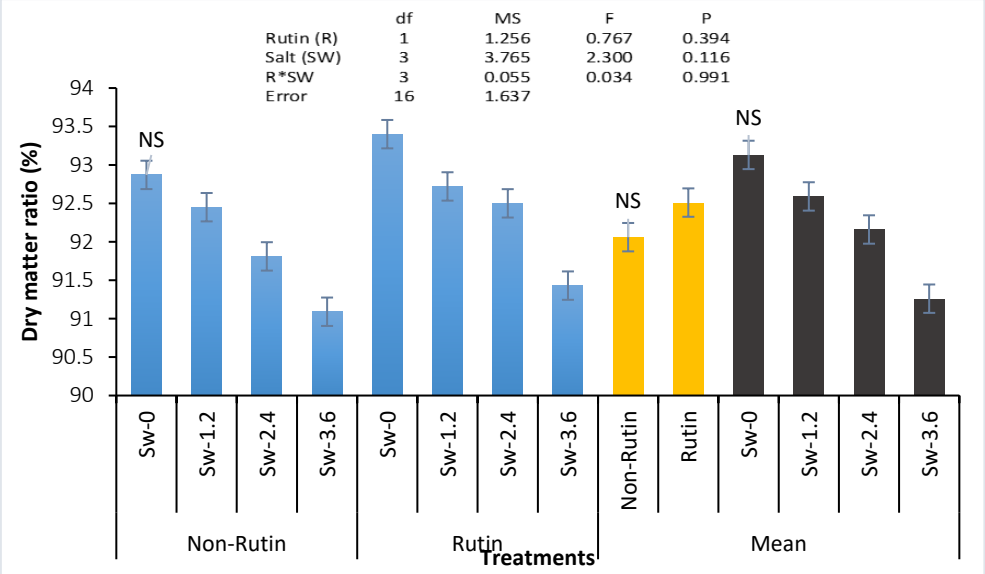


Figure 1. Effect of rutin treatment to dry matter ratio on lettuce plant under salinity stress. **Sw-0**: 0.60 dS m^{-1}, control; **Sw-1.2**: 1.2 dS m^{-1}; **Sw-2.4**: 2.4 dS m^{-1}; **Sw-3.6**: 3.6 dS m^{-1}. **R**: Rutin **Sw**: Saline water. Different letters indicate significant differences between treatments at P<0.05 according to Duncan's multiple range test. "NS" indicates not significant.

Electrolyte leakage (EL) value caused by oxidative damage caused by salinity stress was significantly decreased by rutin treatments ($p<0.01$) (Fig 2). Rutin application reduced the EL value by approximately 15% compared to the control. On the contrary, the EL value increased progressively with increasing saline irrigation applications. To clarify, Sw-1.2, Sw-2.4, and Sw-3.6 salinity stress treatments increased the EL value of lettuce leaves by approximately 1.5, 2, and 3-fold, respectively, compared to the control. Also, the interaction between rutin and saline irrigation treatments was not significant. In previous studies, applying rutin to bean leaves improved tissue tolerance, reduced the harmful effects of salinity on leaf photochemistry, and activated the antioxidant defense mechanism (Ismail et al., 2015). Another study demonstrated that exogenous application of rutin in corn seedlings alleviated the harmful effects of salinity stress (Muslu, 2024). These beneficial effects of rutin are attributed to improved potassium uptake and increased Na+ pumping rate from cells (Ismail et al., 2015). Additionally, rutin, a natural flavonoid, enhances antioxidant resistance by promoting the binding of free radicals. In this study, EL induced by salt stress was significantly reduced with rutin application, suggesting that stress was alleviated in lettuce leaves.

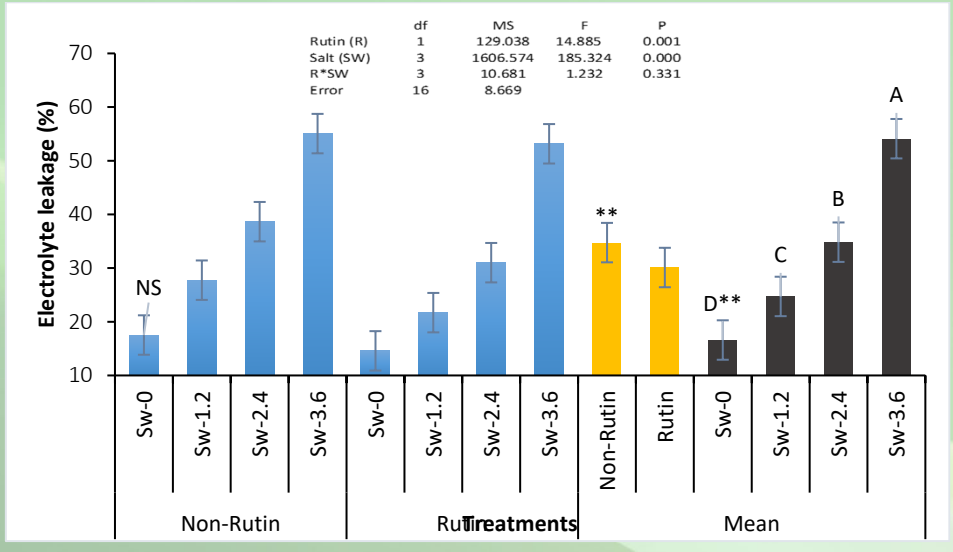


Figure 2. Effect of rutin treatment to electrolyte leakage on lettuce plant under salinity stress. Sw-0: 0.60 dS m^{-1}, control; Sw-1.2: 1.2 dS m^{-1}; Sw-2.4: 2.4 dS m^{-1}; Sw-3.6: 3.6 dS m^{-1}. R: Rutin Sw: Saline water. Different letters indicate significant differences between treatments at P<0.05 according to Duncan's multiple range test. "ns" indicates not significant.

Increasing doses of salinity treatments negatively affected leaf relative water content (LRWC) in lettuce leaves (Fig. 3). Increasing doses of salinity treatments negatively affected leaf relative water content (LRWC) in lettuce leaves. Salinity treatments at doses of 1.2 dS m^{-1}, 2.4 dS m^{-1}, and 3.6 dS m^{-1} decreased LRWC by about 4%, 11%, and 30%, respectively, compared to the control. On the other hand, rutin treatment increased LRWC by about 2% compared to the control, but this effect was not statistically significant. Furthermore, no significant interaction was found between rutin and saline irrigation treatments. LRWC is a valuable measure of the physiological water status of plants (Gonzalez and Gonzalez-Vilar, 2001). In this study, salt stress significantly reduced the LRWC of lettuce. Previous studies have demonstrated decreased LRWC values in lettuce under salt stress (Ekinci et al., 2012; Yildirim et al., 2015). As observed in the present study, the increase in LRWC is known as osmotic adjustment. Osmotic adjustment is one of the factors that can increase salt tolerance (Ashraf 2004; Raza et al. 2006).

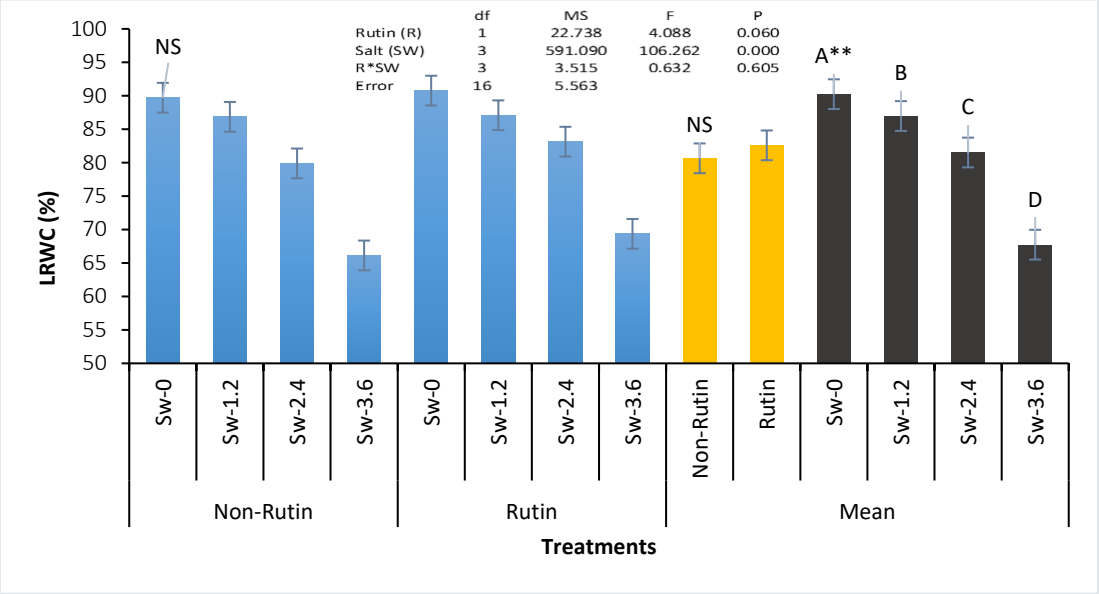


Figure 3. Effect of rutin treatment to leaf relative water content (LRWC) on lettuce plant under salinity stress. Sw-0: 0.60 dS m^{-1}, control; Sw-1.2: 1.2 dS m^{-1}; Sw-2.4: 2.4 dS m^{-1}; Sw-3.6: 3.6 dS m^{-1}. R: Rutin Sw: Saline water. Different letters indicate significant differences between treatments at $P<0.05$ according to Duncan's multiple range test. "ns" indicates not significant.

In summary, the present study concluded that the exogenous application of rutin had beneficial effects on lettuce plants and alleviated the damage caused by salinity stress. The data revealed that rutin promotes plant growth and increases the leaf dry matter content. Based on these results, the application of rutin in lettuce cultivation is recommended. Additionally, it is anticipated that rutin could be used as an alternative to biofertilizers to develop effective plant growth promoters and maximize their use under field conditions.

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The Impacts of Precision Technologies on Cropping System in Developing Countries: A Case Study for Nigeria

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Abstract

Global agricultural systems are undergoing rapid transformation due to increasing food demand. Precision agriculture technologies such as GPS-guided machines, drone and satellite imagery, and IoT-based sensors have emerged as key solutions to optimize farming practices. These technologies increase crop yields, improve resource use efficiency, and support economic profitability. Thanks to these technologies, all processes are data-driven, facilitating decision-making. When all these features are considered together, it is obvious that they also promote environmental sustainability. However, access to these technologies is not the same in every country. Demonstrating the status of access to these technologies, especially in developing countries, will contribute significantly to studies on food security around the world. This review examines the impact of precision agriculture technologies on modern cropping systems, focusing on ways to provide precise control over water, fertilizer, and pesticides, thereby minimizing environmental impacts and input waste. The article also discusses the challenges that smallholder farmers face in adopting precision agriculture technologies, such as high initial costs and limited technological expertise. Recommendations are made to increase the accessibility of precision agriculture technologies through government funding, educational initiatives, and infrastructure improvements. Addressing these barriers is critical to the global adoption of precision agriculture.

Key Words: *Precision agriculture technologies1, Yield optimization2, Resource efficiency3, Sustainability3, GPS-guided machinery5*

Introduction

The agricultural sector is central in the global economy; mainly in the developing countries, it forms part of the economic bedrock. Nevertheless, these countries have various problems in the agricultural sector, such as food shortages, weak farmers' markets, inadequate infrastructure, and adaptive outcomes of climate change (Connolly-Boutin and Smit, 2015). With regard to the agricultural sector, the obstacles to development in the developing regions, including Nigeria, include factors such as low productivity and improved technology and techniques (Adeyemo *et al.*, 2024). The world's population in the future is expected to rise to 9 to 10 billion, and this requirement for food production for the future population calls for enhancements in agricultural productivity of between 60% and 99% (Seelan *et al.*, 2003). Agricultural development, on the other hand, has also accelerated environmental degradation in the last few decades, making the food security mission more challenging (Roberts *et al.*, 2021). A new idea called "smart farming" uses cutting-edge information technology to increase the effectiveness and efficiency of agriculture. The most recent developments in artificial intelligence, automation, and networking allow farmers to administer exact treatments that are decided by machines with superhuman accuracy and to monitor every procedure more effectively (Unal, 2020). For maximum crop yield and quality, smart farming techniques are incorporated into nearly every stage of the growing and even marketing processes. Agriculture production may now be enhanced because of smart farming techniques (Ünal and Kızıldeniz, 2023). The challenges facing the agricultural sector, particularly in the developing world, are daunting given increasing population and climate variability, coupled by scarcer resources. Such challenges have led to the adoption of better farming practices, which replace traditional farming practices. For these complex challenges, mainstream agricultural management strategies have been complemented by precision agricultural technologies, including new sensing tools and hi-tech ICT solutions (Loudjani, 2014). Based on the doctrine of 'getting more out of more', precision agriculture, which is also referred to as precision farming or smart farming, has the potential to reduce the agriculture difficulties encountered by the developing nations. The precision agricultural technologies would increase efficiency and enhance yields with the view to eliminating food insecurity as well as making primary production more sustainable (Erickson and Fausti, 2021). Precision agriculture technologies are employed at critical phases of the agricultural growth cycle, including soil preparation, seeding, crop management, and harvesting. Moreover, precision farming technology have not only helped agricultural and fruit cultivation but have also positively impacted livestock rearing practices. Precision agriculture can be categorised into two segments: precision crop farming, which involves the utilisation of precision farming technologies to address spatial and temporal variability for enhancing crop performance and environmental quality, and precision livestock

farming, which focusses on employing advanced technologies to maximise the productivity of each animal. The farmer seeks to attain improved outcomes in livestock production using this "per animal" methodology (Bucci et al., 2020). Precision crop farming and precision livestock farming are presently influenced by two predominant technical trends: big data and sophisticated analytics capabilities, alongside aerial images, feeding and milking robots, and intelligent sensors. This review article uses secondary sources to analyze various published reports and articles on precision agriculture in developing countries. It aims to provide a comprehensive overview of the topic, identify key findings, trends, and gaps, and propose effective implementation strategies. The review examines the role of precision technologies in increasing crop yields, their effects on resource efficiency, environmental benefits, economic impacts, and challenges and opportunities for future adoption in developing countries, with a particular focus on Nigeria. This paper therefore seeks to examine the adoption of precision agriculture technologies for the development of Nigeria and other developing countries. Specifically, it will draw attention to the difficulties, repercussions, constraints, and direction for applying these technologies. The study can be used as a reference for research and literature for both researchers and farmers to understand how to incorporate technology in the agricultural field.

2. Precision Agriculture Technologies

Precision agriculture has gained tremendous topicality when it comes to the discussion of the new generation of farming techniques. Through the use of GPS autonomously controlled machines, drones, satellite tools, and IOT sensors in cropping systems, information has been swiftly applied in the correct physical application of agricultural inputs with compromise to wastage or overapplication. Several precision technologies stand out in their contribution to modern cropping systems:

1. GPS-Guided Machinery: This was followed by advancements in planting, fertilizing, and spraying systems, which, with the help of GPS, can be sectioned very precisely. These tools provide a way of applying inputs in areas of need while avoiding overlaps and deficit areas. (Randal K. Taylor et al., 2013) study shows that GPS-steered systems help in increasing yields by 15% for crops like corn through consistent application of inputs.
2. Remote Sensing and Drones: Technologies such as drones and satellites allow for quick monitoring of details like crop condition, moisture levels in the soil, and much more. These insights help farmers to intervene whenever possible and probably reduce losses since all the available resources are optimally utilized.
3. IoT-Based Sensors: Some of the significant areas that relate to the use of Internet of Things (IoT) technologies include resource management, soil moisture, and environmental sensors. These sensors supply timely information in protracted intervals with respect to the soil status, hence useful in setting irrigation schedules. Using soil moisture sensors, (Lakhiar *et al.*, 2024) noted that there was a 30% saving of water used in agriculture, meaning that this was an environmental-saving method that also saved money.

2.1 Role of Precision Agriculture on Cropping Systems

Analysing these Precision agriculture technologies, they proffer several benefits to crop management i.e yield increase and better use of resources and environment. Precision yield management uses GPS-controlled application technology and related remote sensing tools for the accurate distribution of fertiliser, herbicide, or water. The distribution of required quantities at the right time benefits both crop yield and balancing the production process across various crops. Studies have shown that it leads to beneficial changes because crops require proper input to produce optimum yield (Sishodia, Ray and Singh, 2020; Lu *et al.*, 2022; Gawande *et al.*, 2023). In the field of resource utilisation and input, Precision agriculture technologies give basic information on the state of the soil, crops, and the general environment. It helps farmers in managing the resources such as water, fertilisers, and pesticides for increasing production and with least reproachable influence on the environment. Connected sensors for the specific and combined water and drone management offer precise procedures, which considerably decrease the wastage of farm resources and increase farm yield (Alahmad, Neményi and Nyéki, 2023; Rajak *et al.*, 2023). IoT technology might have a lot to offer the agricultural sector. To begin with, IoT gives farmers the ability to gather data in real time on the development and health of their crops, giving them important new information. This makes it possible to intervene proactively and make timely modifications to pest control, fertilizer application, and watering techniques. Second, by gathering comprehensive data on meteorological conditions, crop physiology, and growth patterns, IoT technologies improve the precision of yield prediction models (Kour *et al.*, 2024). As concerning the overall environmental impact, precision agriculture reduces the utilisation of agrochemicals as well as the utilisation of natural resources. Precision farming involves the application of a small amount of pesticides different from conventional methods, hence reducing pollution of soil and water. In this regard, they enable a higher or optimum eco-efficient, or least disruptive, yield per unit area relative to conventional practices (Gawande et al., 2023). These technologies have the attributes of tremendous promise for increasing the yield and also for protecting the environment in which farmers conduct their businesses.

2.2 Economic Implications

Precision agriculture technologies entail several advantages in the economic aspect. Although, implementation of precision technologies involves high initial capital investment the returns associated with investment is normally greater. The influx of precision agriculture technologies into a farming operation is often associated with gainful

heights, through the possible gains from subsequent input cutbacks and upticks in product yields. For example, GPS-controlled equipment enables the farmer to minimize seeding rates or overuse fertilizers due to costs of seeds and chemicals (Lu et al., 2022; Randal et al., 2013). Likewise, Smart technologies such as IoT sensors in farming improve irrigation, thereby reducing emission of water and, thus avoiding crop failure because of inadequate water (Rajak *et al.*, 2023).

Furthermore, the precise settings in precision agriculture result from data analysis, which makes it easier to anticipate and predict the ideal time and way of doing things within a farming season (Tantalaki, Souravlas and Roumeliotis, 2019). This ability can lead to more stable income levels, and decreased monetary volatility generally attached to agriculture especially with regard to climate turbulence and unfavourable weather conditions(Monteiro, Santos and Gonçalves, 2021).

2.3 Adoption of Precision Agriculture Technologies in Developing Countries

In developing countries, there are still many problems in agriculture, including low yields, ineffective resource management, and limited accessibility to modern inputs (Bjornlund et al., 2020). Precision agricultural technologies have the potential of reforming this terrain since they provide efficiency solutions to resource poor producers, boost productivity per unit area, and reduce environmental depletion (Balafoutis *et al.*, 2017). As used in many developing countries, high costs and a lack of technical knowledge have slowed the use of precision agricultural technologies, although some countries are starting to show the possibilities of how these technologies might help (Taylor, 2023).

3. Nigeria: A Case Study

Nigeria, with its complex agricultural practices and an increasing population, continues to embrace precision agriculture technologies with the aim of increasing food production and fixing food insecurity and climate change challenges, among others (Bolaji *et al.*, 2024). A number of approaches and pilot-action have been developed to introduce established technologies such as GPS-operated equipment, drones, and IoT sensors in small-holder producers (Ajewole and Oladipo, 2010). In Nigeria, study shows that machinery that utilises GPS is already applied in enhancing the land preparation, planting, and harvesting practices. With this technology, farmers can apply fertilisers or pesticides at the nearest probability, thereby cutting costs and equal amounts of waste (Abdullahi and Sheriff, 2017). For instance, in Northern Nigeria, where commercial farming of crops like maize, wheat, and rice is practiced on a on a large scale, GPS tractors are used for correct planting spacing as well as proper distribution of seeds and fertilizers (Kamai *et al.*, 2020). This has resulted in increased crop yields and decreased input costs for those farmers who can fund such technology. Some state governments have also collaborated with private firms to finance the purchase of GPS-equipped tools for smallholder farmers (Abdullahi and Kumar, 2022). The element of drone technology that has gained significant traction with farmers in Nigerian agriculture is in crop surveillance and pest eradication (Dinrifo *et al.*, 2022). The inspectors that are incorporated into these drones are designed to generate real-time feedback on the status of the crops, the condition of the soil, and the presence of threats from pests and diseases. The gathered information assists the farmers in decision-making processes such as whether and when to irrigate, apply fertiliser, or spray for pesticides. In the southern area of Nigeria, where cocoa and cassava farming are dominant, the apparatus is being employed in surveillance of large plantations (Wossen et al., 2017). In other areas, drones help the farmers to focus on where to make the application, thus increasing productivity and at the same time reducing the usage of agrochemicals. IoT-based sensors have been adopted in various pilot projects in Nigeria concerning water management, mostly in arid regions that receive little or no rain to support irrigation (Sharpe *et al.*, 2022). These sensors measure soil moisture content and inform farmers when to water their crops cross-sectionally. This has been experienced in the northern zones of Nigeria within vegetable production of smallholder farms using IoT sensors to regulate water consumption (Akpan-Etuk, 2024). Due to over irrigation and the use of rollers, the farmers have been able to save water and have healthy crops grown. Moreover, even international organisations like the Food and Agriculture Organisation (FAO) have been funding projects that augment the use of IoT technology in projects that encourage the use of water in regions that are most affected by drought.

3.1 Increased Yield

One of the greatest advantages of using precision agricultural technologies is the gradual augmentation of crop yield in precision agriculture. Precision agricultural technologies' adoption has the potential of reducing food insecurity because in developing countries like Nigeria, small-holder farms dominate the agricultural sector. These have been evidenced by yields of between 5 and 20 percent credited to technologies like GPS auto-steered planting equipment, satellite imagery, and other complementing precision farming technologies (Randal et al., 2013). Smallholder corn farmers in Nigeria who adopted GPS agriculture on planting practices recorded better seed placement, hence better competition for nutrients and water, hence better yields (Taylor et al., 2013). Furthermore, the use of drones proves useful in the development of developing countries as well. For pesticide spraying in the rice production in Nigeria, it has been observed that drones serve the purpose without underlining the crops and enhancing the growth and yield (Hafeez *et al.*, 2023). This is well applicable, especially in the developing countries where pest attacks and unfavourable crop handling are widespread. Drones not only open possibilities for the

efficient usage of pesticides but are also capable of recording the process and enabling farmers to act in a way that would increase productivity (Rejeb *et al.*, 2022). In other parts of Africa, precision agriculture technologies, in as much as they have been implemented appropriately, have resulted in increases in the yields in farming. This shows how precision agricultural technologies are not only recommendable but can also work to transform food production in areas of inadequate resources while helping farmers refine their decisions that would affect the productivity of crops.

3.2 Resource Utilization Efficiency

Enhancement of resource use productivity is the other advantage of precision agricultural technologies, especially for water-constrained and low-nutrient availability areas, common in developing nations. Smart embedded IoT soil moisture sensors and remote sensing technology enable water efficient application, and optimising the use of fertilisers greatly reduces the cost and is eco-friendly (Morchid *et al.*, 2024). Fields that grow vegetables in Nigeria utilising IoT sensors have seen the rate of watering decrease as data from the soil informs the farmers only when the watering is necessary (Douglas et al., 2016). This has led to the cutting down of water usage by 30%, meaning there is no hindrance in crop production (Rajak *et al.*, 2023). The same was the case with precision irrigation. In almond trees in California For at least 30%, water was saved while production rates were kept intact (Christian et al., 2012). It suggests that such countries facing the issue of water scarcity can adopt a policy of water conservation, a significant factor in most of the developing countries. In regions such as the northern part of Nigeria, which is faced with a scarcity of water, the use of IoT-based devices for irrigation has been identified as sustainable in the improvement of water use efficiency in agriculture (Familade et al., 2016).

In addition, there is an added advantage of precision agricultural technologies in that the application of the nutrients is made more accurate. Because several farmers in the developing countries fail to use fertilisers properly because of inadequate training, precision agricultural technologies enable costly fertiliser usage, therefore eliminating chances of nutrient leaching, which causes pollution. Numerous experiments have demonstrated the potential for the precision method of nutrient application to cut input costs by 10–25% on different farming practices, thereby increasing its profitability and efficiency (Hedley, 2015). This is especially relevant when cultivating crops and livestock in high-risk areas that impel smallholder farmers to work under severe budget constraints and with minimal capital.

3.3 Environmental Benefits

The technologies used in precision agriculture have a vital part in reducing the negative effects of concentrated agricultural activities on the environment (Getahun, Kefale and Gelaye, 2024). As these technologies allow input application to be targeted, these decreases the instances whereby fertilizers and pesticides are used in amounts that can pollute nearby ecosystems (Dehghani *et al.*, 2024). For example, (Wang *et al.*, 2019) showed that precision application of fertilizers lowered nitrogen leaching to a significant level, hence saving water bodies from pollution by nutrients. In addition, precision farming enables farmers to reduce the addition of inputs onto the soil, which has negative effects on the quality of the soil (Monteiro, Santos and Gonçalves, 2021) In the same way, agricultural Precision agriculture technologies also cause the carbon footprint of agriculture to be minimized through decreasing the usage of heavy agriculture tools and enhancing the wise utilization of natural resources in line with climate change (Sanyaolu and Sadowski, 2024).

3.4 Economic Gains

It has been realised that the adoption of precision agricultural technologies involves certain overall costs, which are nevertheless paid off in the long run by the stable advantages that are accorded to the shrewd users of these technologies of precision agriculture. A paper by (Munz and Schuele, 2022) shows that farmers who adopt precision technology use fewer inputs, produce many sellable outcomes, and therefore generate more revenues. As examples, IoT-implemented irrigation systems and GPS-navigated machinery have been proven to decrease input waste and increase operational efficiency and total yield. Comparative cross-sectional case studies indicate that it is possible to recover the initial investment cost of precision agriculture equipment in two to three years from the onset of pilot projects (Robertson et al., 2007). In the economies of developing countries such as Nigeria, the implication of precision agricultural technologies is observed in aspects of market prediction and management of agricultural businesses. Many IoT-based systems for irrigation, levee control, and GPS-based machinery have helped farmers in making intelligent decisions about the use of resources and better resistance to weather fluctuations (Familade et al., 2016).

This operational resilience results in a relatively stable income stream, which cushions the shocks that smallholder farmers generally experience due to climate change and poor physical infrastructure. Nonetheless, some studies have hypothesised that precision agricultural technologies may have positive effects on the economics of crops (Robertson et al.,2007; Munz and Schuele, 2022); nonetheless, numerous challenges persist for the application of Precision agricultural technologies, mainly because of the high costs of establishment, which are relatively high for final consumers and especially the smallholders in the developing countries. Precision agriculture technologies are capital intensive in terms of equipment, knowledge, and parts for maintenance, which most smallholder farmers cannot access. In sub-Saharan Africa, the majority of farmers practice small-scale farming, and, therefore, they are

unable to obtain capital and financing sources to purchase these technologies. This limiting factor reduces viability and causes an imbalance of access, with large-gain commercial farms and resource-poor smallholders. However, the expense of using precision technologies can aggravate their applicability in smallholder farmers' context: the cost of operation. Some of these technologies depend on internet connections, especially on infrastructure, which unfortunately is not a strong point in the rural areas of developing countries. With poor investment in infrastructure and technical support, the total economic benefit of precision agricultural technologies can plateau, and this is a disadvantage to the smallholder farmers. In order to overcome the above challenges, there require subsidies assumed by governments and/or international organisations or cheaper credits to support the development of precision agricultural technologies accessible to small farmers more easily. Moreover, joint initiatives of private entities, non-governmental organisations, and the government can ease actual cost restrictions by offering such options as shared technology or cooperation, allowing smallholders to buy precision technologies collectively without bearing the full expense. However, this is not all because the long-term strategic benefits of implementing precision agricultural technologies and betterment in economic prospects are positive signs. Appropriate qualitative financial and physical inputs assist in increasing smaller-holder farmer incomes, decreasing input costs, and improving yields, thereby bringing improvements in the economics of developing countries.

3.5 Challenges to Adoption

Despite benefits achievable through Precision Agriculture Technologies, which include higher yields, effective use of resources, and profitability, their uptake is limited by several constraints, especially in the developing world. These are mainly high initial costs, technology inaccessible, and poor infrastructure that hampers smallholder farmers as well as hinders wide implementation of precision agricultural technologies. The first and perhaps one of the main challenges is that the use of Precision agricultural technologies—GPS—to control machinery, IoT sensors, and drones, among other applications, is expensive to acquire and integrate (Talaviya *et al.*, 2020). These technologies demand large capital investments, most of which smallholder farmers in developing countries cannot afford (Say *et al.*, 2017). Despite the ability to lower input costs and ramp up profitability in the long run, the high up-front cost dooms most farmers to missing out on these opportunities. Now, there is no subsidy or funds from other independent sources for the small-scale farmers in the developing countries, such as Nigeria, to afford to purchase and maintain those precision technologies. A further issue is the difficulty of the technical know-how in terms of running and managing Precision Agriculture instruments. Smallholders in developing countries are often not trained enough to understand the data from GPS and IoT sensors and other modern tools (Tey and Brindal, 2012). Inadequate access to educational programs and agricultural extension services also enhances this problem because it becomes hard for farmers to optimally utilise precision agricultural technologies. It also helps to avoid adopting new technologies, as farmers are reluctant to spend money on instruments with which they are unfamiliar. Thus, lack of facility and the cost of acquiring and implementing precision agricultural technologies remain major impediments to their adoption in developing nations. Some of the precision agriculture technologies, especially those based on IoT technologies, depend on internet connectivity to operate efficiently. But in the remote and rural areas of the developing world, internet connections can be scarce or totally non-existent (Kumar *et al.*, 2024). This lack of fundamental investment complicates the application of technologies whose effectiveness depends on wired data links or real-time tracking, for example, IoT sensors to monitor irrigation needs or drone coverage for crop concerns. Besides, the existing transport and energy infrastructure in the rural areas poses additional challenges to the usage of precision agricultural technologies (Gbadamosi and Olorunfemi, 2016). Equipment like UAVs and tractors that form part of precision agriculture applications need to be powered constantly, an aspect that is always elusive in many developing countries. Lack of infrastructure and the relevant necessary equipment means poor application of the technologies that precision agriculture offers to farmers, mostly in rural areas. These challenges, in addition to a lack of equal access to technology and the possibility of uses of digital technology to augment and expand inequalities identified between large commercial farms and smallholder farmers, paint the future of African agriculture with potential inequalities. While large-scale, well-endowed farms are able to embrace and incorporate precision agricultural technologies, smallholder farmers, who could also benefit enormously from improved productivity, do not get service. Adoption of IoT technology in agriculture is not without its obstacles. One factor preventing IoT device adoption has been noted as being a lack of technical expertise. To properly integrate IoT technology into their agricultural methods, farmers might need assistance and training (Jabbari *et al.*, 2023). Meeting these challenges calls for collective action from governments, non-governmental organisations, and intergovernmental organizations. Subsidies—in the form of cash injection, cheap credit, or grants—could assist smallholder farmers to cover a major proportion of Precision agricultural technologies upfront costs. Also, expenditures on education and training would help farmers acquire the technical know-how to manage precise instruments productively. Lastly, sustainable advancement in rural physical capital, particularly internet and reliable energy, is important in improving the use of precision agriculture technologies in the developing countries.

4.0 Conclusion

The findings presented in this work highlight the prospects of the modern cropping systems based on the principles of precision agriculture. On this basis, Precision agriculture technologies demonstrate a progressive action plan that would lead to improved crop yields, better uses of resources and generally the sustainability of the environment

in agricultural production. Nevertheless, issues concerning the cost of implementing these technologies such as, infrastructure, or technical know-how affects the farming fraternity and should be dealt with, in order to make the realized benefits a reality at all levels of farming across the globe.

4.1 Recommendations

i. Government and Policy Support: Tax credit rebates or affordable interest rates on funds required for precision agriculture technology should be offered by governments. The Precision agricultural technologies should also feature in government food production, sustainable agriculture, and climate change policies.

ii. Training and Capacity Building: To operate and maintain precision devices, farmers require special education and training. Various farmers, with the help of agricultural extension services, universities, and international agricultural organisations can provide such programs.

iii. Infrastructure Development: Precision agricultural technologies that introduce the use of IoT require a stabilised framework; this consists of the internet. Therefore, expenditure in these technologies can yet aid the extension of rural digital facilities.

iv. Financing and Subsidy Models: Policies should also be proposed to supply capital for small farmers to purchase Precision agricultural technologies by cooperatives or through public, non-private partnerships. Asking to "premium" risks, small farmers could coordinate an order of precise technology and divide the gains in efficiency and productivity.

v. Research and Development: More studies should develop literature on how to improve Precision agricultural technologies acceptance, how to reduce the cost of the materials, and adapt them to the different production systems prevalent in the developing world. Second, empirical examination of the resilience of Precision agricultural technologies on power dynamics in the rural labour market and economy has to be done.

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ID: 754

Bio-Transformation of Agricultural and Municipal Waste into High-Value Resources: Advances, Challenges, and Future Prospects

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Abstract

Biotransformation technologies are one of the most promising fields in sustainable waste management, where farm and municipal waste is transformed into high-value bioproducts. This review explores the latest advances in microbial, enzymatic, and thermochemical processes that facilitate conversion of biomass and organic residues into bioenergy, bioplastics, biofertilizers, and bio-based chemicals. Scalable technologies such as anaerobic digestion, composting, fermentation, and gasification are emphasized with emphasis on process optimization and energy efficiency. The application of genetically engineered microbes and synthetic biology in enhancing conversion efficiency and product selectivity is examined. In addition, decentralized biorefineries are proposed as an economic model for circular bioeconomies to incorporate into local waste systems. The paper also examines key challenges that must be addressed, including heterogeneity of feedstock, microbial contamination, economic barriers, and policy uncertainty. Socio-economic and environmental impacts are evaluated using sustainability metrics and case studies from elsewhere. Future research directions stress the need for hybrid technologies, integrated systems, and real-time monitoring technologies in order to maximize the use of resources with the maximum possible efficiency and minimum possible environmental effects.

Keywords: *Anaerobic digestion, Bio-based products, Biorefineries, Biotransformation, Organic waste, Sustainable waste management*

ID: 755

E-Waste Management in the Digital Age: Global Trends, Toxicological Risks, and Green Recovery Technologies

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Abstract
The exponential growth of electronic waste (e-waste) has become an urgent environmental and public health concern due to its toxic composition and propensity for illegal disposal. This review synthesizes e-waste generation, composition, and policy responses globally. It discusses the toxicological risks posed by heavy metals, brominated flame retardants, and persistent organic pollutants contained in the majority of end-of-life electronics. The paper then goes on to discuss emerging green technologies for e-waste recycling such as hydrometallurgical leaching, bioleaching, supercritical fluid extraction, and microfactory systems that minimize environmental damage while maximizing material recovery. It also explores the impact of producer responsibility, integration of the informal sector, and eco-design on the evolution of sustainable e-waste management systems. Global policies, for example, Basel Convention and WEEE Directive, are critically discussed alongside problems of transboundary dumping, informal recycling hazards, and inadequate public enlightenment. The article concludes by propounding multi-stakeholder frameworks towards creating secure, efficient, and equitable circular e-waste systems.
Keywords: E-waste, Toxicity, Recycling technology, Bioleaching, Producer responsibility, Circular electronics

ID: 756

Pollution to Solution: Nano-Enabled Strategies in Wastewater Treatment and Resource Recovery

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Abstract
Nanotechnology has been a breakthrough technology in wastewater treatment and resource recovery because it possesses high surface area, reactivity, and selectivity in adsorption. This review discusses the most recent nano-enabled methods for the removal of contaminants including heavy metals, pharmaceuticals, pathogens, and microplastics from industrial and domestic wastewater. Nanomaterials such as carbon nanotubes, graphene oxide, metal-organic frameworks (MOFs), and magnetic nanoparticles are emphasized in the context of action mechanism, regeneration ability, and environmental safety. Hybrid systems that incorporate nanomaterials with membrane filtration, photocatalysis, and electrochemical treatment for optimal use are discussed in the article. Special consideration is given to the recovery of useful resources like nutrients and rare earth elements during treatment. Environmental risk assessment, regulatory barriers, and lifecycle concerns are also addressed to achieve responsible deployment and development of nano-based technology. This review concludes by proposing future directions such as green synthesis, AI-driven nano-design, and decentralized nano-filtration units for smart and sustainable wastewater management.

Keywords: Nanotechnology, Wastewater treatment, Nanomaterials, Resource recovery, Water purification, Environmental safety

ID: 757

The Psychology of Nature Connection: How Environmental Education Develops Ecological Empathy and Action

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Abstract

There is a growing body of psychological evidence that demonstrates the profound benefits of nature connection for human well-being and ecological action. This review paper discusses how environmental education generates ecological empathy and pro-environmental behavior through psychological mechanisms. Based on the synthesis of environmental psychology research, social cognition, and education science, the paper explores experiential change of nature-based learning experiences influencing children's and adults' sense of identity, emotional well-being, and ecological citizenship. Relevance includes forming biophilia, the role of sensory immersion, and cognitive reorganization achieved through experiential learning in natural settings. The article also examines barriers such as urbanisation, screen addiction, and socio-economic deprivation, which limit access to nature and undermine learning outcomes. Moreover, the paper examines how teachers, mentors, and role models are engaged in facilitating emotional connection to the environment. Through international case studies and educational programs analysis, the review demonstrates that fostering a psychological sense of nature connection improves not only environmental learning outcomes but also other mental health goals. The paper proposes that fostering ecological empathy through systematic and informal educational interventions is essential to facilitate progress in community and institutional sustainability transformations.

Keywords: Nature connection, Ecological empathy, Environmental psychology, Experiential learning, Pro-environmental behavior, Environmental identity

ID: 758

Green Minds, Greener Futures: Integrating Ecopsychology into Environmental Curricula for Holistic Sustainability

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Abstract

The integration of ecopsychology into environmental education is a worthwhile approach to building sustainability by tapping cognitive knowledge and emotional affinity with nature. This review examines ecopsychological principles grounded on the human-nature relationship embedded within formal and informal curricula for ecological literacy and psychological wellbeing. The essay chronicles ecopsychology's evolution as well as the relevance of its framework in modern socio-environmental challenges of climate distress, eco-grief, and emotional detachment from the natural world. An integrative review of ecopsychological pedagogies such as mindfulness in nature, eco-art therapy, and reflective journaling shows their efficacy in building emotional resilience and environmentalism. Grounded on a multidisciplinary integration, this review shows how ecopsychological interventions in schools can initiate heightened awareness, sense of responsibility, and long-term commitment to taking care of the environment. It also presents case study examples from different learning environments—schools, universities, and community programs—highlighting their challenges and achievements. The paper concludes by proposing a model curriculum that incorporates ecopsychological approaches into sustainability education in order to connect the psychological and ecological dimensions of learning. Last but not least, this initiative instills a new paradigm for environmental education—one where students are empowered not only to know the environment but to experience and care for it.

Keywords: Ecopsychology, Environmental curriculum, Climate anxiety, Nature-based education, Sustainability, Emotional resilience

ID: 759

Beyond Green Barriers: Genetic Engineering Progress toward Enhanced Phytoremediation Efficiency

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Abstract
Phytoremediation has been acknowledged as an environment-friendly and cost-effective method for avoiding environmental contamination, particularly in contaminated soil and water. However, the plant uptake capacity limit and stress resistance limit prevent its large-scale application as a green technology. Current advances in genetic engineering offer promising answers to overcome these limitations through enhanced metal uptake, detoxification processes, and biomass yield. This review compiles the latest breakthroughs in molecular engineering, including CRISPR/Cas-mediated genome editing, overexpression of metal transporter genes, and transgenic insertion of antioxidant pathways. Omics tools such as transcriptomics, proteomics, and metabolomics have expedited the identification of novel gene targets associated with hyperaccumulation and resistance. Furthermore, synthetic biology is also enabling the development of modular genetic circuits to control phytoremediation reactions under different environmental conditions. The review also examines biosafety concerns, ecological impact, and regulation of genetically engineered phytoremediators. Overall, biotechnology application in phytoremediation not only increases its potential for remediation of the environment but also results in the development of circular and robust biotechnologies towards sustainable development across the globe.

Keywords: Genetic engineering, Phytoremediation, CRISPR/Cas9, Hyperaccumulators, Molecular biology, Transgenic plants

ID: 760

Rooted Solutions: Rhizosphere Microbiome Synergies in Phytoremediation of Contaminated Soils

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Abstract

Rhizosphere is a dynamically biological interface where plant roots intimately interact with microbes in soil and form complex synergistic interactions influencing nutrient turnover and pollutant transformation. For phytoremediation, the plant-microbiome interface is also critical in controlling contaminant bioavailability and detoxification. This review highlights recent advances in the use of plant growth-promoting rhizobacteria (PGPR), mycorrhizal fungi, and endophytes to make phytoremediation more efficient. Some functions are microbial pollutant transformation, increased root surface area, induction of stress-responsive genes, and secretion of chelating agents. Microbiome engineering strategies like inoculation with pollutant-degrading bacteria consortia or microbiome transplant from stress-resistant ecosystems are also addressed in the review. Special emphasis is placed on microbial-assisted remediation of heavy metals, hydrocarbons, and emerging contaminants like PFAS. Future directions include metagenomics and synthetic microbial communities (SynComs) to address the manipulation of rhizosphere functions. Leverage and knowledge of such subterranean partnerships can lead to ecologically safe and highly effective phytoremediation processes.

Keywords: Rhizosphere, Microbiome, PGPR, Soil remediation, Mycorrhizae, Endophytes

ID: 761

Constructed Wetlands and Aquatic Phytoremediation: Nature-Based Solutions for Water Purification

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Abstract

Constructed wetlands (CWs) leverage the phytoremediation potential of aquatic vegetation to remove polluted water through natural biological processes. This current review offers a comprehensive overview of different CW types—free water surface, subsurface flow, and hybrid systems—and their efficiencies in removing nutrients, pathogens, heavy metals, and organic contaminants. Special emphasis is laid on the selection of appropriate macrophytes such as *Phragmites australis*, *Typha latifolia*, and *Eichhornia crassipes* with elevated uptake and tolerance capacity. The mechanisms of pollutant removal are through sedimentation, root zone filtration, microbial breakdown, and uptake by the plant. Urban landscape and agriculture landscape case studies highlight efficient CW usage in wastewater treatment, stormwater management, and industrial effluent regulation. The integration of CWs with green infrastructure and urban planning is a term used to explain a sustainable decentralized wastewater treatment system. The invasiveness of plants, seasonality, and long-term maintenance issues are also clarified. CWs present an environmentally friendly, low-energy, and cheap option in congruence with water security and sustainable development strategies.

Keywords: Constructed wetlands, Aquatic phytoremediation, Macrophytes, Wastewater treatment, Green infrastructure, Nature-based solutions

ID: 762

Hyperaccumulators Redefined: Innovation in Phytoextraction and Phytomining for Resource Recovery

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Abstract
Hyperaccumulator plants possess the unique ability to absorb exceptionally high concentrations of heavy metals without exhibiting any symptoms of phytotoxicity. This property renders them strong candidates for phytoextraction and phytomining—ecological technologies for the remediation and resource recovery. This review chronicles the latest advances in the discovery, cultivation, and commercialization of hyperaccumulator species such as *Alyssum murale* and *Noccaea caerulescens*. Principal physiological traits, including metal transport mechanisms, chelator production, and vacuolar sequestration, are described. Novel field trials indicate the potential for nickel, cadmium, and rare earth element recovery in mining and post-industrial settings. Economic assessments indicate that phytomining could yield economic advantages to land owners and restore poor soils. Agronomic management, harvesting technologies for increased metal uptake and yield, and soil amendments are also presented in the review. As global demand for critical minerals rises, hyperaccumulators offer a sustainable option to conventional mining, fitting environmental rehabilitation alongside economic viability.

Keywords: Hyperaccumulators, Phytoextraction, Phytomining, Critical minerals, Soil remediation, Resource recovery

ID: 763

Phytoremediation of Emerging Contaminants: Phytoremediating Pharmaceuticals, Microplastics, and PFAS

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Abstract

As the list of environmental pollutants increases, phytoremediation is faced with new challenges in the remediation of recalcitrant and complex emerging pollutants such as pharmaceuticals, personal care products (PPCPs), per- and polyfluoroalkyl substances (PFAS), and microplastics. Traditional remediation techniques are often not effective in removing these compounds from the environment, whereas phytoremediation is a green and sustainable option. This review provides a current synthesis of how some plant species can take up, degrade, or immobilize such emerging contaminants. The emphasis is placed on the processes of phytotransformation, phytodegradation, and rhizodegradation, particularly in riparian and wetland ecosystems. The synergistic role of rhizosphere microorganisms in the degradation of complex chemical compounds is discussed. Case studies demonstrate success with *Vetiveria zizanioides*, Populus spp., and *Lemna minor* species for reducing contaminant load in wastewater and river sediments. The challenge of bioaccumulation, toxicity of metabolites, and detection by analysis are addressed, and suggestions for future research on transgenic and hybrid systems are made. Phytoremediation is shown to be an intriguing solution for combining environmental rehabilitation with contaminant-specific detoxification strategies.

Keywords: Emerging contaminants, PFAS, Pharmaceuticals, Microplastics, Phytodegradation, Wastewater treatment

ID: 764

Nanotechnology-Assisted Phytoremediation: A Hybrid Strategy for Superior Contaminant Removal

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Abstract

Nanotechnology is revolutionizing phytoremediation by enhancing plant-microbe interaction, pollutant bioavailability, and detoxification mechanisms. This review examines the synergistic potential of combining nanoparticles with plants for promoting the uptake and degradation of heavy metals, pesticides, and organic pollutants. Engineered nanoparticles such as nano-iron, nano-TiO_2, and carbon-based nanomaterials are shown to trigger root exudates, enhance enzyme activities, and modulate redox conditions in the rhizosphere. The review also discusses nanoparticle-mediated delivery systems for plant growth regulators and microbial inoculants. Problems of nanoparticle toxicity, persistence, and ecotoxicological impacts are viewed critically. Case studies demonstrate the effectiveness of nanotechnology-enhanced systems over classical phytoremediation systems in contaminated soils, water, and sediments. This combinatorial concept opens new fields in environmental nanobiotechnology and offers promise for real-time site-specific remediation with improved efficacy and control.

Keywords: Nanotechnology, Nanoparticles, Hybrid phytoremediation, Nano-iron, Environmental nanobiotech, Plant-nano interactions

ID: 765

Phytoremediation and Soil Health: Restoring Microbial Diversity and Functionality in Degraded Lands

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Abstract

Degradation of soil due to heavy metal contamination and industrial effluents is a critical threat to soil fertility, microbial diversity, and ecosystem services. Phytoremediation, in addition to removing pollutants, can restore soil health by improving physicochemical properties and enhancing biological activity. The review discusses how phytoremediation influences soil pH, organic carbon, and nutrient cycling, leading to microbial biomass development and enzymatic activities being enhanced. Brassica juncea and Helianthus annuus are some of the plants that facilitate recolonization by microbes as they exude sugars, amino acids, and secondary metabolites that promote microbial growth. Co-remediation strategies like composting, biochar, and microbial consortia are also addressed. Such treatment has the potential to facilitate soil recolonization, trigger plant-facilitative microbe interaction, and increase crop productivity following remediation. Soil health indicator monitoring is highlighted in phytoremediation assessment protocols. By establishing a biologically active and resilient microbial community in the soil, phytoremediation can be an integral part of sustainable land management and ecological rehabilitation.

Keywords: Soil fertility, Microbial diversity, Soil enzymes, Co-remediation, Soil health, Land restoration

ID: 766

Climate Change and the Caspian Sea Basin: Hydrological Alterations and Socio-Ecological Impacts

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Abstract
The largest enclosed inland water body in the world, the Caspian Sea, is undergoing unprecedented change due to climate change, local hydrological perturbations, and anthropogenic stressors. This review presents an extended critique of how climate-related changes—though temperature changes, precipitation regimes, evaporation rates, and river inflows—are reshaping the hydrology and ecology of the Caspian Sea basin. Long-term satellite data and hydrological models predict alarming sea level drops, threatening coastal ecosystems, biodiversity, and infrastructure. Southern and eastern littoral zone ecosystems are particularly vulnerable, with migratory bird species, endemic fish, and benthic communities being more susceptible to habitat destruction, salinization, and pollution concentration. Socioeconomic effects include the disruption of fisheries, port infrastructure, agriculture, and traditional livelihoods. Furthermore, reduced water run-off from big rivers such as the Volga, Kura, and Ural, coupled with damming and irrigation, intensifies basin-wide water stress and geopolitics tension among littoral states. This review also investigates the feedback mechanisms relating climate change to sediment transport, wetland shrinkage, and invasive species proliferation. Significantly, it highlights knowledge gaps and emphasizes the need for regional climate-resilient policy, transboundary cooperation, and investment in early warning systems. Adaptive measures such as integrated water resource management (IWRM), nature-based solutions (NbS), and ecological restoration of deltas and wetlands are proposed as pathways toward mitigation. Overall, the Caspian Sea is a vulnerable socio-ecological system where climatic change, human activity, and governance intersect—calling for cooperative, multidisciplinary action.

Keywords: Caspian Sea, climate change, hydrological alteration, loss of biodiversity, regional cooperation, resilience of ecosystems

ID: 767

Molecular Detection and Detoxification of Aflatoxins: Recent Advances in Biotechnology and Nanomaterials

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Abstract

Aflatoxins, highly toxic and carcinogenic Aspergillus-produced mycotoxins, represent a global threat to world food safety and public health. Recent biotechnology and nanotechnology advances hold auspicious opportunities for aflatoxin detection and detoxification. Molecular detection techniques, including enzyme-linked immunosorbent assay (ELISA), polymerase chain reaction (PCR), and new biosensors, have dramatically improved aflatoxin detection speed and sensitivity in foodstuffs and feed. These technologies and new nanomaterials, including nanoparticles, carbon nanotubes, and graphene oxide, are fast becoming potent tools for aflatoxin extraction from tainted foodstuffs and agricultural crops. Nanomaterials possess unique features such as high surface area, functionalization, and reusability, which enable more efficient and sustainable detoxification processes. Moreover, nanomaterial-based systems can also be employed in food packaging and storage systems to reduce aflatoxin contamination. In this review, the latest molecular techniques and the potential of nanotechnology in aflatoxin detoxification are highlighted, as well as a general overview of their application in food safety, environmental monitoring, and agricultural sustainability. By examining the unique advantages of nanomaterials, this paper highlights the potential for scalable, cost-effective solutions to prevent aflatoxin contamination at large scales.

Keywords: Aflatoxins, molecular detection, biotechnology, nanomaterials, biosensors, detoxification.

ID: 768

Bioremediation of Aflatoxins: Harnessing Microbial and Enzymatic Tools for Mycotoxin Degradation

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Abstract

Bioremediation, utilizing microorganisms and enzymes to degrade toxic pollutants, has proven an effective method of minimizing aflatoxin contamination. This article focuses on new developments in the microbial degradation of aflatoxins, explaining the function contributed by bacteria, fungi, and yeast strains to the degradation of such toxic compounds by enzymatic mechanisms. Individual enzymes such as cytochrome P450 monooxygenases, laccases, and peroxidases are essential to aflatoxin detoxification, catalyzing the conversion of aflatoxins into non-toxic metabolites. Microbial consortia synergistically degrading aflatoxins have also been shown with greater efficiency compared to individual species. Recent developments in enzyme engineering and synthetic biology may further improve the effectiveness of bioremediation by producing more stable and targeted enzymes for aflatoxin degradation. The review also takes into account the factors influencing the process of bioremediation, including environmental factors, nutrient availability, and microbial community dynamics. Besides, problems such as scalability and effectiveness of such methods in real field conditions are also addressed, with the solutions being microbial consortia and genetic engineering. A comprehensive review of the microbial and enzymatic methods of aflatoxin degradation has been given in this paper, highlighting their sustainability and eco-friendliness as effective alternatives to chemical detoxification processes.

Keywords: Bioremediation, aflatoxins, microorganisms, enzymes, degradation, detoxification.

ID: 769

Emerging Industrial Pollutants in Aquatic Systems: Monitoring, Risk Evaluation, and Green Remediation Strategies

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Abstract

Aquatic ecosystems are increasingly threatened by the emergence of newly industrializing pollutants such as personal care products, pharmaceuticals, and endocrine-disrupting chemicals. The majority of these pollutants are not effectively removed by traditional wastewater treatment and accumulate in rivers, lakes, and coastal waters, posing gigantic threats to aquatic organisms and human health. This review addresses the monitoring of newly identified pollutants in aquatic environments, focusing on the use of advanced analytical techniques, such as liquid chromatography-mass spectrometry (LC-MS) and high-resolution mass spectrometry (HRMS), for the identification of trace concentrations. It also addresses the risk assessment of these contaminants, with emphasis on the challenges in assessing their long-term environmental and ecological impacts. Green remediation technologies, such as phytoremediation, bioremediation, and natural sorbents, offer green alternatives to chemical remediation. The overview presents a comprehensive overview of the effectiveness and limitations of these technologies, with focus on applicability for large-scale use in industrial settings. Furthermore, the application of bioindicators in assessing ecosystem health as well as pollutant bioaccumulation is addressed. This article ends by urging for holistic monitoring and remediation models that combine cutting-edge technologies with green approaches to address the new challenges posed by industrial contaminants in aquatic ecosystems.

Keywords: Industrial contaminants, aquatic ecosystems, monitoring, risk assessment, green remediation, bioindicators.

ID: 770

Geohealth Frontiers: Linking Geological Substrates to Public Health and Ecosystem Risk Assessment

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Abstract

Geohealth is a new interdiscipline of study that investigates how geological conditions affect public health and ecosystem integrity. This review takes into account the ways in which the fabric and composition of geological substrates—mineralized rocks, volcanic soils, sedimentary basins—can influence environmental quality and, consequently, human health. Natural impurities like arsenic, fluoride, and heavy metals typically have geogenic sources and leach into groundwater or concentrate in agricultural products, thus inflicting long-term health issues like carcinogenesis, fluorosis, and organ damage. In industrial belts and mining regions, anthropogenic activities are likely to initiate geological vulnerabilities, releasing toxicants that enhance environmental and health hazards. By using examples of case studies from Iran, India, and Sub-Saharan Africa, this paper provides regional variation in geological exposure to risk. New advances in geo-mapping, remote sensing, and isotopic fingerprinting now enable accurate spatial correlation of geologic substrates with disease clusters for early intervention. Further, the inclusion of geological data in environmental risk models enhances the accuracy of ecosystem health assessment and land-use planning. This review proposes a geohealth strategy based on cross-sectoral collaboration among geologists, ecologists, and public health experts to predict and mitigate environmental hazards. The novelty of this work lies in its emphasis on proactive integration of geological data into health monitoring systems, policy, and climate adaptation planning.

Keywords: Geohealth, geological substrates, environmental risk, heavy metals, groundwater, disease mapping.

ID: 771

Regenerative Soil Management in Agriculture: Unleashing Carbon Sequestration and Climate Mitigation Potential

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Abstract

Soil is an integral part of the global carbon cycle and a key factor in climate regulation. This review identifies regenerative soil management (RSM) as a revolutionary approach under climate-resilient agriculture for increasing soil carbon sequestration, restoring degraded lands, and developing resilience against environmental stresses. Leading RSM practices—such as conservation tillage, agroforestry, biochar incorporation, green manuring, and composting—not only improve soil structure and soil fertility but also allow for long-term stabilization of atmospheric CO_2 in soil organic matter. Developing studies indicate that RSM can potentially raise soil organic carbon (SOC) content by up to 1.5% annually, which is a considerable input towards global climate change mitigation goals. The review also brings to the fore the central role played by soil microbiota, particularly arbuscular mycorrhizal fungi, in facilitating carbon stabilization and nutrient cycling. Cutting-edge predictive tools, including RothC and CENTURY models, provide strong frameworks for simulating SOC dynamics under various regenerative scenarios. However, widespread scaling up of RSM is constrained by insecure land tenure, low farmer uptake, and policy support deficits. This review suggests the incorporation of RSM in national climate action plans, sustainable development agendas, and carbon trading schemes. Notably, it provides a region-specific analysis of the feasibility of RSM in arid and semi-arid areas, where it has immense potential in reversing desertification, improving soil health, and supporting food security. The novelty of this study is its integrative approach that connects biophysical processes and socio-economic enablers to demonstrate the co-benefits of soil rejuvenation for climate resilience, biodiversity conservation, and rural livelihoods.

Keywords: Regenerative agriculture, soil carbon, carbon sequestration, climate change, agroecology, land restoration.

ID: 772

Climate-Smart Agriculture and Soil Resilience: Strategies for Arid and Semi-Arid Regions

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Abstract

Arid and semi-arid regions face enhanced food insecurity due to rising climate variability, land degradation, and water scarcity. Climate-smart agriculture (CSA) has an integrated approach to enhancing the environment sustainability, productivity, and resilience of crops under such tight conditions. From this review, CSA strategies, including precision irrigation (e.g., drip irrigation system), drought-tolerant cultivars, conservation agriculture, mulching, and organic soil manures, improve soil retention capacity, reduce erosion, and stabilize yield under changing climate. In addition, soil microbiome enhancement through the use of biofertilizers and microbial consortia is an area to advance drought resistance. Case study-based context-specific adaptations in Iran, the Sahel, and the Indian Thar Desert are highlighted, such as zai pits, sand mulching, and fog-harvesting. The review also mentions the deployment of digital agriculture—remote sensing, artificial intelligence-based weather forecasting, and sensor-based monitoring of soil—to enable decision-making. Socio-economic barriers to CSA adoption, including access to finance, knowledge transfer, and land tenure insecurity, are examined. Policy frameworks for inducing CSA using incentives, extension, and integrated watershed management are also discussed. The importance of context-specific and participatory approaches to CSA is discussed in this paper. Its novelty lies in the integration of indigenous ecological insights with new climate-resilient technologies for adaptive capacity building and food system resilience in risk-prone lands.

Keywords: Climate-smart agriculture, soil resilience, arid lands, drought adaptation, precision farming, microbial biofertilizers.

ID: 773

The Economic and Practical Considerations of Encapsulation in Ruminant Nutrition

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Abstract
Technology involve in encapsulating nutrients is one of the reliable tools in ruminant nutrition that provide a better way in which nutrients are efficiently utilized, animal performance enhancement with a minimal negative effects to the environment. This study reviews the economic and practical implications of nutrient encapsulation in ruminant nutrition with an emphasis on its potential in bioactive compounds protection, controlled release of nutrients and feed efficiency improvement. Despite the benefits incorporation of encapsulation technology in ruminant nutrition brings such as sensitive nutrients stability enhancement and their systematic delivery in the ruminant digestive system, its uses in ruminant nutrition is associated with scalability limitation, high costs and practical challenges. The costs involved in encapsulation is higher when compared with the conventional additives because of the complexity of the materials involved in processing. Its integration relied on production scalability, stable storage and conformity with traditional feeding. Its economic feasibility depends on its importance in the performance and health of ruminant animals, or its environmental impact. Challenges involved in its practical application include consistency, technical know-how, and variability in performance of encapsulated products. Further researches are very important to reduce the costs and improve its delivery. Therefore, the encapsulation technology advancement in ruminant nutrition is reliant on achieving a balance between innovative solutions, cost-effectiveness and implementation practically at the farm level.
Keywords: Encapsulation, Economic, Costs, Ruminant, Nutrition

Introduction

Ruminant animals plays important in maintaining global food security, by providing meat, milk and other products that care for human nutrition (Xie et al., 2021). Nevertheless, the ruminant production is faced with several challenges such as inefficiencies in nutrient use, pollution to the environment, and rising costs related to feed. Therefore, enhancing feed efficiency and reducing losses of nutrients are very vital in ensuring ruminant production sustainability and productivity.

Encapsulation technology improves ruminant nutrition in a way of protecting and ensuring the targeted delivery of additives in feed. The process include enclosing the nutrient or additive in a protective layer of material ensuring that it bypass the rumen to the targeted digestive site (Garba & Fırıncıoğlu, 2023). It also ensures that unpalatable odors of the additives are masked and also protect sensitive nutrients and additives from degradation (Wei et al., 2022).

Studies from previous researches suggested the possible importance of encapsulation in improving ruminant nutrition. Example rumen protected amino acids (lysine, methionine) encapsulation was reported to improve milk production and synthesis of protein in dairy cattle (Zanton et al., 2014). Also the encapsulation of polyunsaturated fatty acids has been reported to increase their chances of integration into milk and meat without compromising rumen function (Jenkins et al., 2008). Encapsulation was also used to protect probiotics, enzymes, and phytogenic additives therefore, improving their efficiency and stability in ruminant diets (McAllister et al., 2011).

Encapsulation technology methods such as spray drying, coacervation, and extrusion have presented a wide range of application in ruminant nutrition. For example, encapsulation by spra-drying was used to protect essential oils which possesses an antimicrobial properties from rumen degradation (Benchaar et al., 2015). Coacervation encapsulation method was also used to protect vitamins and minerals ensuring their stability and bioavailability in diets of ruminant animals (Sanchez et al., 2017).

However, despite all these developments, there is a limited adoption of encapsulation technology in ruminant nutrition. With high costs of production, scalability and performance of encapsulated products variability, the commercialize application of these technology is difficult. There is also lack of standardized methods for evaluation of economic feasibility and efficiency of encapsulation technologies in ruminant nutrition.

While the potential benefits of encapsulation in ruminant nutrition are well-documented, several knowledge gaps remain. First, there is limited understanding of the interactions between encapsulation materials and rumen microbes, which can influence the release and utilization of encapsulated nutrients. Second, the long-term effects of encapsulated products on animal health and productivity require further investigation. Third, there is a need for cost-benefit analyses to evaluate the economic feasibility of encapsulation technologies in large-scale ruminant production systems. Finally, the environmental impacts of encapsulation materials and processes have not been thoroughly assessed.

The purpose of this paper is to provide a comprehensive review of the economic and practical considerations of encapsulation in ruminant feeding systems. By synthesizing existing literature, this paper aims to identify key factors influencing the efficacy and feasibility of encapsulation technologies, highlight potential challenges, and propose future research directions to optimize their use in ruminant nutrition.

Encapsulation Technology

Encapsulation is a technology in which nutrients, bioactive compounds and other nutrients components are enclosed in a protective coat or matrix. The technology is important in ruminant nutrition because of its ability to allow a targeted deliverance of vital feed and nutrients bioactive components and protecting them from rumen degradation hence ensuring their release in the lower digestive tract (Garba & Fırıncıoğlu, 2023). Biovailability, stability and efficiency of nutrients can be improve by encapsulation leading to the overall animal performance improvement and minimal environmental effects (Garba & Fırıncıoğlu, 2023).

Diiferent methods of encapsulation have been reported with each showcasing a promising advantages. Spray drying is particularly employed for heat sensitive compounds like essential oils, vitamins and probiotics through forming a dry particles often rapid drying (Ré, 1998). Coacervation is used for hydrophobic compounds such as fatty acids in which a separate colloidal phase is used to encapsulate the substances (Dong et al., 2011). Extrusion works for enzymes and probiotics (Kailasapathy, 2002). Liposome encapsulation technique uses lipid bilayers to enclose sensitive nutrients like vitamins (Mozafari et al., 2008), while emulsion-based methods help stabilize PUFAs and lipids (McClements, 2012).

Encapsulation of rumen protected methionine and lysine was reported to boost milk yield and milk protein content in dairy cows (Zanton et al. 2014). PUFAs encapsulation also enhance their transfer into milk and meat without compromising rumen function (Jenkins et al., 2008). This technology also allows for controlled nutrient release, improving absorption. Encapsulated starch, for example, provides post-ruminal energy, supporting better growth in beef cattle (Huntington et al., 2006). Additionally, encapsulation safeguards probiotics and enzymes, enhancing their stability and effectiveness. Protected probiotics have been shown to improve rumen health and overall animal performance (McAllister et al., 2011). Phytogenic additives such as essential oils often degrade in the rumen, but encapsulation ensures they reach the lower digestive tract intact, maximizing their antimicrobial and antioxidant benefits (Benchaar et al., 2015).

Economic Considerations

Production Costs: The high production costs associated with the implementation of encapsulation process is one of the factor that hinder its widespread adoption in ruminant nutrition especially by the small scale farmers (Xie et al. 2021). These high costs result from the complex nature of the encapsulation process because of the need for a specialized equipment and machines and the encapsulation materials (Xie et al., 2021). For example high quality lipids or polymers to be used in encapsulation can increase costs of production tremendously (Sánchez et al., 2017).

Cost-Benefit: Encapsulation allows nutrients such as amino acids, vitamins, minerals, enzymes, and probiotics to bypass rumen degradation and be released at optimal sites in the digestive tract. Nutrient bioavailability is increased by the target delivery which leads to better conversion of feed, weight, and milk production (Almassri et al. 2024: Garba & Fırıncıoğlu, 2023). Feed accounts for up to 70% of total cost of production in ruminant nutrition, therefore any improvement in feed efficiency can save cost and increase profit (Almassri et al. 2024). While encapsulation technologies can improve nutrient utilization and animal performance, their economic viability depends on the cost-benefit ratio. For example, the use of rumen-protected amino acids may be economically justified in high-producing dairy cows but not in low-producing animals. Similarly, the cost of encapsulating essential oils or probiotics must be weighed against the potential benefits in terms of improved animal health and productivity (Benchaar et al., 2015).

Scalability: Another important factor that influence the economic feasibility of encapsulation technology in ruminant nutrition is scalability, even though there is a cost effectiveness in a laboratory-scale encapsulation procedures, scaling up the processes for commercial production pose a challenge and it is expensive. For example, the production of encapsulated probiotics or enzymes on a large scale requires specialized equipment and stringent quality control measures, which can increase production costs (McAllister et al., 2011).

Practical Considerations

Technical challenges: The implementation of encapsulation technology in ruminant nutrition is faced with challenges involving the technical know-how including the appropriate encapsulation material selection, encapsulation process optimization and product stability and efficiency evaluation. The encapsulation material choice have effect on the release rate of the compounds encapsulated which also affects its efficiency in the rumen (Sánchez et al., 2017).

Variability in Performance: Encapsulation material type, size and structure of capsules, rumen condition are the factors that influence the performance of the encapsulated products. This variability makes it difficult to determine

the encapsulated products efficiency in different feeding systems. McAllister et al. (2011) reported that probiotics encapsulated efficiency may vary depending on the rumen microbial activity and pH.

The impacts of encapsulation materials and process on the environment have not been thoroughly evaluated. Biodegradability and environmental persistence as a result of the use of synthetic polymers as an encapsulation material may raise environmental concern. The production of encapsulation materials may also generate waste and emissions leading to environmental pollution (Sánchez et al., 2017).

Conclusion

Encapsulation technology offers several importance in ruminant nutrition such as improved nutrient utilization, animal performance enhancement and minimal environmental impacts. Nevertheless, its adoption in ruminant nutrition is hindered by high costs of production, technical know-how, and limited scalability. It's recommended that future studies should focus on finding and developing a cost-effective and scalable encapsulation processes, long-term effects of encapsulated products on animal health and productivity evaluation as well as evaluating the impacts of encapsulation material and processes to the environment

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The Influence of Black Cumin Seed (*Nigella sativa*) Supplementation on Growth Performance, Carcass Characteristics, and Meat Quality in Poultry: A Comprehensive Review

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Abstract

Over the last decade, there has been a surge of interest in natural feed additives as sustainable alternatives to antibiotics in poultry nutrition. The global restriction on the use of antibiotic growth promoters (AGPs) in animal nutrition has accelerated the search for safe, effective natural alternatives. Among various phytogenic additives, *Nigella sativa* (black cumin) has emerged as a promising alternate owing to its diverse pharmacologically active compounds, including thymoquinone, dithymoquinone, thymol, carvacrol, nigellicine, and nigellidine. These bioactive constituents exhibit a broad spectrum of biological activities, such as antibacterial, antioxidant, anti-inflammatory, immunomodulatory, hepatoprotective, and digestive-enhancing effects. In poultry, dietary supplementation with *Nigella sativa* seeds has demonstrated considerable improvements in growth performance, feed conversion ratio, carcass yield, and meat quality, as well as enhanced immune responses and intestinal health. It effectively reduces intestinal pH and pathogenic load while promoting beneficial gut microbiota. In layer birds, supplementation is associated with enhanced egg quality and improved overall health status. Beyond productivity metrics, the antioxidant properties of black cumin contribute to better meat preservation and shelf-life by reducing oxidative spoilage. Its antimicrobial activity against both Gram-positive and Gram-negative bacteria highlights its potential as a natural substitute for synthetic antibiotics and preservatives. Optimal inclusion levels ranging from 1–2% have been shown to yield beneficial outcomes without adverse effects. This review consolidates current findings on the efficacy of *Nigella sativa* in poultry diets, emphasizing its role in promoting growth, improving meat and egg quality, and supporting sustainable poultry production. Future research should aim to standardize inclusion levels, investigate synergistic effects with other natural additives like probiotics, and evaluate its long-term effects under diverse management systems.

Key Words: *Nigella sativa, black cumin, poultry nutrition, growth performance, meat quality, natural antioxidants, gut health, feed efficiency, sustainability*

Introduction

Text The global poultry industry serves as a vital source of high-quality animal protein, facing increasing demands as world population growth necessitates 60% greater food production by 2050 (Asghar et al., 2021; Akram et al., 2019; Al-Beitawi et al., 2008; Hanboonsong et al., 2013). This protein crisis has led to concerning practices, including the widespread use of synthetic chemicals and antibiotics as growth promoters in poultry production (Asghar et al., 2022; Akram et al., 2021; Güler and Dalkiliç, 2009; Miles et al., 2006; Naımatı et al., 2022). While these substances effectively control pathogenic microorganisms like Salmonella, Escherichia coli, and Enterococci, their routine use has led to alarming consequences including antibiotic resistance and tissue residues in animal products (Schwarz et al., 2001; Sierżant et al., 2023; Tauseef et al., 2017).

In recent years, the poultry industry has witnessed growing interest in phytogenic feed additives, driven by consumer demand for natural and residue-free animal products. Among these, *Nigella sativa* (black cumin) has emerged as particularly noteworthy due to its rich phytochemical composition and multifaceted therapeutic properties. With a history of traditional use in herbal medicine, this remarkable botanical has demonstrated antioxidant, antimicrobial, immunomodulatory, and growth-promoting characteristics that position it as an ideal candidate for sustainable poultry nutrition (Asghar et al., 2022)

The European Union's 2006 ban on antibiotic growth promoters Toghyani et al., (2010) has accelerated research into natural alternatives, particularly following evidence linking antibiotic residues in meat and eggs to human health risks (Rahmatnejad et al., 2009; Issa et al., 2012). This regulatory shift has forced the industry to reconcile production efficiency with evolving consumer preferences for food products containing beneficial bioactive compounds (Asghar et al., 2024; Cofrades et al., 2008; Sajid et al., 2023; Jia et al., 2021). Modern consumers increasingly prioritize not only food safety but also nutritional quality seeking products with natural antioxidants,

optimal fatty acid profiles, and reduced chemical additives (Hygreeva et al., 2014; Pisulewski et al., 2005; Capitani et al., 2013; Decker et al., 2010).

Scientific investigations have consequently focused on various natural alternatives including essential oils, phytobiotics, and medicinal plants (Elgayyar et al., 2001; Valero et al., 2003; Jamroz et al., 2002; Jang et al., 2004; Ramakrishna et al., 2003). These substances offer the dual advantage of antimicrobial activity without promoting resistance while potentially enhancing digestive function (Jamroz et al., 2002; Jang et al., 2004; Ramakrishna et al., 2003). The search for effective alternatives has gained urgency as dietary patterns shift toward healthier options that may reduce risks of cardiovascular disease, cancer, and obesity (Hygreeva et al., 2014; Pisulewski et al., 2005; Capitani et al., 2013; Decker et al., 2010).

Nigella sativa distinguishes itself among phytogenic options through its exceptional nutritional profile, containing high-quality proteins, essential amino acids, vital minerals (calcium, potassium, phosphorus, magnesium) El-Ghorab et al. (2003); Sultan et al. (2009), and an impressive array of bioactive compounds including thymoquinone, carvacrol, and thymol (Nasir, 2005). These components confer numerous benefits including antimicrobial activity (Oroojalian et al., 2010), antioxidant capacity (Attia et al., 2019; Baghban-Kanani et al., 2019; Khoobani et al., 2019), gastrointestinal protection (Jamroz et al., 2002), and growth promotion potential (Al-Beitawi et al., 2009).

The essential oil fraction of black cumin contains at least 18 bioactive compounds, predominantly carvone (66%) and limonene (50%), along with gamma-terpinene, cuminaldehyde, and various flavonoids (Jalilzadeh-Amin et al., 2011; Moghtader et al., 2009; Yalçın et al., 2009)[27-29]. These compounds exhibit diverse pharmacological activities including antimicrobial (Oroojalian et al., 2010), anti-inflammatory (Hajhashemi et al., 2011), and muscle relaxant effects (Jalilzadeh-Amin et al., 2011), making *Nigella sativa* a comprehensive natural solution for poultry production challenges.

This review systematically evaluates current knowledge regarding *Nigella sativa* supplementation in poultry nutrition, with particular emphasis on its effects on growth performance, carcass characteristics, and meat quality parameters in broiler chickens and laying hens. By synthesizing existing research, we aim to clarify the mechanisms of action, optimal inclusion levels, and practical applications of this promising phytogenic additive in modern poultry production systems.

Phytochemical Composition of *Nigella sativa*

Nigella sativa, commonly known as black cumin, is a flowering plant of the Ranunculaceae family that has garnered considerable scientific attention due to its complex and potent phytochemical profile. The seeds of N. sativa contain a wide array of biologically active compounds that contribute to its therapeutic efficacy and functional role as a phytogenic feed additive in poultry nutrition. The most significant constituent of N. sativa seeds is thymoquinone (TQ), a monoterpene compound that accounts for the majority of its pharmacological activity. Thymoquinone exhibits strong antioxidant, antimicrobial, anti-inflammatory, anticancer, and immunomodulatory effects, making it a key contributor to the plant's functional applications (Nasir, 2005; Attia et al., 2019; Baghban-Kanani et al., 2019; Khoobani et al., 2019). In addition to thymoquinone, other notable constituents include dithymoquinone, thymohydroquinone, thymol, carvacrol, nigellidine, nigellicine, and α-hederin, all of which have demonstrated bioactivity in both in vitro and in vivo studies (Al-Beitawi et al., 2009; Jalilzadeh-Amin et al., 2011; Moghtader et al., 2009). The essential oil content of N. sativa seeds ranges from 0.4% to 2.5%, and its composition varies depending on geographical origin, cultivation conditions, and extraction methods. Major volatile compounds include carvone (up to 66%), limonene (approximately 50%), p-cymene, γ-terpinene, trans-anethole, cuminaldehyde, and β-pinene, many of which contribute to the plant's antimicrobial, digestive-stimulant, and anti-inflammatory properties (Jalilzadeh-Amin et al., 2011; Moghtader et al., 2009; Yalçın et al., 2009; Oroojalian et al., 2009).

Apart from volatile oils, N. sativa seeds are also a rich source of fixed oils (up to 35–38%), composed primarily of unsaturated fatty acids such as linoleic acid (50–60%), oleic acid (20–30%), and smaller quantities of palmitic and stearic acids (Hajhashemi et al., 2011). These fatty acids contribute to the plant's nutritional value and are beneficial for energy metabolism, lipid regulation, and cellular function in poultry. Additionally, the seeds contain significant amounts of proteins (20–25%), dietary fiber, saponins, alkaloids, and phenolic compounds, including flavonoids and tannins. These molecules play important roles in modulating oxidative stress, enhancing nutrient absorption, and improving gut health (Gilani et al., 2004; Ferdous et al., 1992; ElKamali et al., 1998). Mineral content is also substantial in N. sativa, with appreciable levels of calcium, potassium, magnesium, iron, phosphorus, zinc, and selenium, which are essential for skeletal development, enzyme function, and overall physiological balance in poultry (El-Ghorab et al., 2003; Sultan et al., 2009).

In summary, the phytochemical richness of N. sativa underpins its multifaceted biological activities. The synergistic action of its bioactive compounds supports its efficacy as a natural growth promoter, antimicrobial agent, antioxidant, and immune enhancer, reinforcing its potential as a sustainable alternative to conventional feed additives in poultry nutrition.

Effects of N. sativa on Feed intake and Growth Performance

Numerous studies have demonstrated that dietary supplementation with *Nigella sativa* (commonly referred to as black cumin seed, BCS) positively influences average daily weight gain (ADWG) and overall growth performance in poultry. Research conducted over the past two decades consistently indicates improved body weight parameters across various poultry species and production systems following BCS inclusion in feed (Osman, 2002; El-Bagir et al., 2006; Guler et al., 2006; Durrani et al., 2007; Abu-Dieyeh and Abu-Darwish, 2008; Al-Beitawi et al., 2009; Ashayerizadeh et al., 2009; Erener et al., 2010; Ismail, 2011; Khan et al., 2012; Yatoo et al., 2012; Saleh, 2014; Jahan et al., 2015). For instance, Osman (2002) reported a significant increase in ADWG in broiler chickens supplemented with BCS oil. El-Bagir et al. (2006) found that the inclusion of BCS at levels of 10 or 30 g/kg significantly improved final body weight in laying hens. Guler et al. (2006) observed that broilers fed diets containing both BCS (10 g/kg) and antibiotics achieved the highest ADWG compared to the control. Likewise, Abu-Dieyeh and Abu-Darwish (2008) showed that diets containing 10 and 15 g/kg BCS led to significantly enhanced ADWG over a four-week feeding period. Similar improvements were reported by Erener et al. (2010), Khan et al. (2012), and Yatoo et al. (2012), with the latter highlighting the highest gains in groups receiving 0.5% BCS.

These growth-enhancing effects are potentially linked to improved nutrient digestibility, stimulated bile secretion, and activation of pancreatic enzymes, resulting in more efficient fat digestion and nutrient absorption (Kumar et al., 2017a). Key active components of BCS, including thymoquinone (approx. 60%), carvone, anethole, carvacrol, and 4-terpineol, exert antibacterial and antioxidant actions, while simultaneously stimulating digestive enzyme activity in both intestinal mucosa and pancreas (Abu-Dieyeh and Abu-Darwish, 2008). Additionally, Mandour et al. (1998) suggested that BCS may elevate thyroxine levels, thereby enhancing basal metabolic rate and contributing to growth.

The feed intake response to BCS supplementation, however, remains inconsistent across the literature. Some studies reported a significant increase in average daily feed intake (ADFI) following BCS inclusion (Osman and El-Barody, 1999; Abou-El-Soud, 2000; Erener et al., 2010; Ismail, 2011; Yatoo et al., 2012). For example, Osman and El-Barody (1999) noted increased ADFI with powdered BCS at inclusion levels ranging from 2 to 10 g/kg. Similarly, Yatoo et al. (2012) observed increased feed intake across all growth phases in broilers fed 1% BCS, while Abou-El-Soud (2000) reported the highest ADFI in quail chicks supplemented with 2% whole crushed BCS. In contrast, other investigations documented a decline in ADFI upon BCS supplementation. Osman (2002) and Abbas and Ahmed (2010) noted reduced feed intake in broilers receiving 1–2% BCS oil, while Szczerbińska et al. (2012) and Çetin et al. (2008) observed dose-dependent decreases in ADFI in quail and partridges, respectively. Durrani et al. (2007) and Shewita and Taha (2011) also reported significant reductions in feed intake at higher BCS inclusion levels. Several other studies found no significant impact of BCS supplementation on feed intake (Denli et al., 2004; Guler et al., 2006; Ashayerizadeh et al., 2009; Khalaji et al., 2011; Ghasemi et al., 2014; Al-Mufarrej, 2014; Saleh, 2014). These divergent findings may be attributed to variations in BCS form (whole seed, oil, extract), dosage, poultry species, and experimental conditions, including feed composition and rearing environment.

With regard to feed conversion ratio (FCR), most studies indicate a favorable effect of BCS supplementation. Significant improvements in FCR have been reported in trials by Guler et al. (2006), Durrani et al. (2007), Abu-Dieyeh and Abu-Darwish (2008), Erener et al. (2010), Toghyani et al. (2010), Yatoo et al. (2012), and others. Guler et al. (2006) showed that 1% BCS improved FCR by approximately 5% over the control group, while Abu-Dieyeh and Abu-Darwish (2008) achieved the best efficiency with 1.5% BCS supplementation. Nonetheless, not all studies found a consistent or significant effect on FCR. For instance, Nasir and Grashorn (2010) and Abbas and Ahmed (2010) reported non-significant improvements, and Majeed et al. (2010) even observed a deterioration in FCR with 0.25% BCS inclusion. Similarly, Al-Beitawi and El-Ghousein (2008) reported dose-dependent declines in feed efficiency at BCS inclusion rates above 1.5%. The variability in FCR responses may relate to several factors, including baseline diet composition, bird health status, housing conditions, and potential interactions between BCS bioactives and gut microbiota. It has been proposed that the benefits of phytogenic additives such as BCS are more pronounced under suboptimal conditions, where the antimicrobial and digestive-stimulatory effects may compensate for environmental or dietary challenges (Lee et al., 2003).

In conclusion, while the majority of studies support the growth-promoting and feed efficiency-enhancing effects of *Nigella sativa* supplementation in poultry, the impact on feed intake appears to be context-dependent. Differences in experimental design, dietary formulations, and the form and level of BCS supplementation likely account for the observed inconsistencies. Further research is warranted to define optimal inclusion rates and to elucidate the mechanisms underpinning these performance improvements.

Effects on Carcass Traits

The inclusion of *Nigella sativa* (Black Cumin Seed, BCS) in poultry diets has demonstrated variable yet generally beneficial effects on carcass traits and internal organ development. Several studies have reported improvements in dressing percentage, breast muscle yield, and reductions in abdominal fat deposition, suggesting enhanced protein

metabolism and modulation of lipid pathways. For instance, Guler et al. (2006) and Toghyani et al. (2010) observed significant increases in carcass yield, as well as the weights of the liver, breast, thigh, wing, and neck in broilers supplemented with 1% BCS. However, heart weight remained unaffected. Similarly, studies such as those by Erener et al. (2010) and Saleh (2014) confirmed increases in carcass and breast muscle weights, though some found no significant changes in liver or edible organ weights. On the contrary, several researchers have reported inconsistent or non-significant effects. For example, El-Ghammry et al. (2002) and Abbas and Ahmed (2010) observed a decrease in dressing percentage with BCS inclusion, while Ismail (2011) noted no significant changes in most carcass parameters, including dressing yield, edible organ weight, and abdominal fat.

In terms of fat metabolism, Durrani et al. (2007) and Abaza et al. (2008) highlighted BCS's lypolytic effects, especially the significant reduction in abdominal fat when BCS oil was added at low concentrations (e.g., 0.1%), indicating a potential diversion of energy from fat deposition toward more beneficial physiological processes. Nonetheless, conflicting evidence also exists. Some studies, such as those by Al-Beitawi and El-Ghousein (2008) and Khalaji et al. (2011), reported no significant differences in internal organ weights or carcass traits across varying levels of crushed or uncrushed BCS. Moreover, while an increase in breast meat weight was consistently observed in multiple studies (Jahan et al., 2015), parameters like thigh and wing weights, skin, and drumstick weights often varied depending on BCS concentration, bird age, and experimental conditions.

Additionally, several studies have indicated that while meat composition—such as protein and fat content—might be altered positively by BCS supplementation (Hermes et al., 2009, 2011), there are often no significant effects on attributes like meat tenderness, pH, shear force, or electrical conductivity (Majeed et al., 2010; Khan et al., 2012). Some negative impacts were also reported, such as increased cooking losses and decreased dressing percentage with 1% whole-ground black cumin (Ismail, 2011). The disparities in results may be attributed to differences in BCS form (oil, meal, crushed or uncrushed seeds), inclusion levels, bird genetics, and environmental or management factors. Nevertheless, the frequent observation of increased breast muscle yield suggests that BCS positively influences protein metabolism and mineral bioavailability in poultry, making it a promising natural additive for improving carcass traits under controlled dietary strategies.

Effects on Meat Quality, Chemical Composition, and Antioxidant Properties in Poultry

The inclusion of BCS in poultry diets has shown a promising impact on meat quality attributes, primarily through its antioxidant mechanisms. These effects are attributed to bioactive compounds such as thymoquinone, carvacrol, anethole, and 4-terpineol, which help delay lipid oxidation, reduce microbial load, and extend shelf life. Improvements in meat quality parameters have been consistently reported, including enhanced meat color—likely due to the stabilization of myoglobin—better water-holding capacity and tenderness, and reduced lipid peroxidation. Studies have demonstrated that BCS supplementation leads to increased dry matter (DM), crude protein (CP), and ether extract (EE) content in breast and thigh muscles, with the most significant results observed at 10 g/kg diet (Kumar et al., 2018). Similar findings were reported by Al-Beitawi and El-Ghousein (2008), who noted improved DM and CP levels in breast meat with 15 g/kg BCS inclusion, though leg meat was less responsive.

The antioxidant effects of BCS are also evident at the biochemical level. Supplementation has been shown to elevate antioxidant enzyme activities such as glutathione peroxidase and superoxide dismutase in thigh muscle, while simultaneously decreasing malondialdehyde (MDA) levels, a key marker of lipid peroxidation (Rahman and Kim, 2016; Guler et al., 2007). Kumar et al. (2018) observed increased ferric reducing antioxidant power (FRAP) in serum and meat, suggesting an improved oxidative stability, especially after storage at 4°C. While the peroxide values in thigh meat remained largely unaffected, breast meat showed decreased lipid peroxidation when ether extract content was considered, reinforcing the meat-protective effects of BCS. Moreover, these antioxidant properties may be linked to the influence of BCS on endocrine function, particularly thyroid activity, which affects protein synthesis and energy metabolism (Hermes et al., 2011).

In addition to improving oxidative stability, BCS influences the fatty acid profile of poultry meat. Though research is limited, some studies indicate increased polyunsaturated fatty acid (PUFA) content and reduced fat oxidation in BCS-treated meat (Kumar et al., 2018). PUFA enrichment is particularly beneficial, given its susceptibility to oxidative degradation and its importance in human nutrition. Methanolic extracts of BCS have revealed high phenolic content—such as syringic acid, hydroxybenzoic acid, and p-coumaric acid—which exhibit potent in vitro antioxidant activity (Mariod et al., 2009). The capacity of BCS to scavenge free radicals, inhibit cyclooxygenase and lipoxygenase pathways, and regulate enzymes like glutathione S-transferase and catalase has been confirmed in both poultry and rodent models (Badary et al., 2003; Tuluce et al., 2009). Notably, diets containing 0.5–1% BCS significantly reduced erythrocyte MDA levels and increased glutathione concentrations, reflecting decreased oxidative stress and enhanced cellular defense mechanisms.

Collectively, these findings underscore the potential of *Nigella sativa* as a natural feed additive to enhance meat quality in broilers. Its integration into poultry diets not only improves physicochemical properties and nutritional value of meat but also supports oxidative stability, thereby contributing to better shelf life and consumer acceptability.

Effects on Immunity and Health Status

Numerous studies have investigated the immuno-potentiative activity of Black Cumin Seed (BCS) in poultry, highlighting its potential role in enhancing immune responses and overall health. Kumar et al. (2017a) demonstrated a quadratic increase in antibody titres against Newcastle Disease Virus (NDV) in broiler chickens supplemented with BCS at 5, 10, and 20 g/kg diet at 35 days of age, although no significant difference was observed at 28 days. Similarly, Al-Beitawi et al. (2009) reported a significant enhancement in antibody titres against NDV and Infectious Bursal Disease Virus (IBDV) at 42 days of age following BCS supplementation in chickens vaccinated at appropriate intervals. Durrani et al. (2007) also noted increased antibody production when BCS was included at 40 g/kg diet. In contrast, other studies (Toghyani et al., 2010; Shewita and Taha, 2011) reported no significant changes in antibody titres against NDV and influenza virus, attributing these results to the use of lower BCS doses or reduced concentrations of active compounds in the BCS formulations used.

In terms of lymphoid organ development, findings remain inconsistent across studies. Kumar et al. (2018) observed that spleen weight decreased linearly while bursa weight increased linearly with increasing BCS supplementation. Toghyani et al. (2010) found that lymphoid organ weights were positively influenced at 2 and 4 g/kg of BCS. Al-Mufarrej (2014) reported enhanced immune responsiveness with 10 or 14 g/kg BCS supplementation; however, no significant differences in bursa or spleen weights were observed at 21 and 35 days post-vaccination. Other investigations, such as those by El-Deek et al. (2009) and Yatoo et al. (2012), failed to find statistically significant differences in immune organ weights, although some variation was noted, possibly due to external factors such as feed contamination by mycotoxins (Cazaban et al., 2015).

Several bioactive compounds in BCS, including thymoquinone, carvacrol, nigellimine, thymol, and nigellicine, are believed to contribute to its immunomodulatory effects due to their antibacterial, antioxidant, and anti-inflammatory properties. These compounds likely stimulate immune cell activity, promote antibody production, and offer protection against oxidative stress and pathogenic microorganisms. Supporting this, El-Tahir et al. (1993) found that supplementation of BCS in human volunteers enhanced immune function by improving the helper T cell to suppressor T cell ratio and increasing natural killer cell activity. Similarly, Dorucu et al. (2009) observed significantly elevated serum protein and immunoglobulin levels in rainbow trout fed with BCS.

BCS also demonstrated the potential to reduce poultry mortality rates. Supplementation with 1.5% BCS in layer diets decreased mortality from 16.67% to 4.17%, while 1% BCS in broiler diets reduced mortality from 3.5% to 2% (Al-Jabre et al., 2003). Moreover, Hermes et al. (2011) noted improved bird survival and health under heat stress conditions with BCS supplementation, attributing the effects to enhanced immunity and antimicrobial action. However, some studies, such as Ismail (2011), reported no significant effect on mortality rates, reflecting the variability in outcomes depending on the dosage, environmental factors, and health status of the flock.

In summary, while the immunomodulatory potential of BCS is supported by several studies—particularly in enhancing NDV and IBDV antibody titres, supporting lymphoid organ development, and reducing mortality—the findings are not universally consistent. Variations in dosage, form of BCS used, bird age, vaccination schedule, and environmental conditions appear to significantly influence the outcomes. These inconsistencies underscore the need for standardized protocols in future research to better elucidate the immunological benefits of BCS in poultry nutrition.

Effects of *Nigella sativa* on Egg Production and Quality in Laying Poultry

The impact of *Nigella sativa* (black cumin) on egg production and quality in laying poultry has been widely studied, with results often showing variation depending on the dosage, form, and species involved. Several studies have reported positive outcomes; for instance, supplementation with 1.5% powdered black cumin or 3% whole seeds has significantly enhanced egg production in laying hens. Conversely, El-Bagir et al. (2006) observed a reduction in egg production by approximately 9% and 16% with the inclusion of 1% and 3% black cumin, respectively, without any influence on egg dimensions. This decline was attributed to increased final body weight, suggesting that the energy from N. sativa oil may be directed more towards weight gain than egg output. Another possible explanation is the associated decrease in egg yolk cholesterol, as lower cholesterol levels—essential for egg formation—can negatively affect egg production. Elkin et al. (1993) demonstrated that a 30% reduction in yolk cholesterol via a synthetic HMG-CoA reductase inhibitor resulted in a 20% drop in egg production, implying a critical threshold for cholesterol levels below which normal egg production cannot be sustained.

In terms of egg quality, supplementation with black cumin has shown promising results. A 1.5% inclusion increased egg weight from 54 to 58 grams, and 1% black cumin extract was effective in enhancing both egg weight and shell characteristics in quails. Additionally, diets with 2–3% black seed were associated with significant improvements in shell thickness and strength, whereas 1% or lower did not yield similar benefits. However, some studies reported no significant effect on egg production or composition. For example, Bolukbasi et al. (2009) found that N. sativa oil did not influence egg weight, production, or the proportion of yolk, albumen, and shell, although a 3 ml/kg inclusion reduced the Haugh unit, a measure of egg albumen quality. Notably, a 3% black cumin seed diet resulted in reductions in egg yolk total lipids, cholesterol, phospholipids, and triacylglycerols by 34%, 45%, 11%, and 20%, respectively—an outcome considered beneficial for human consumption. The exact mechanism of

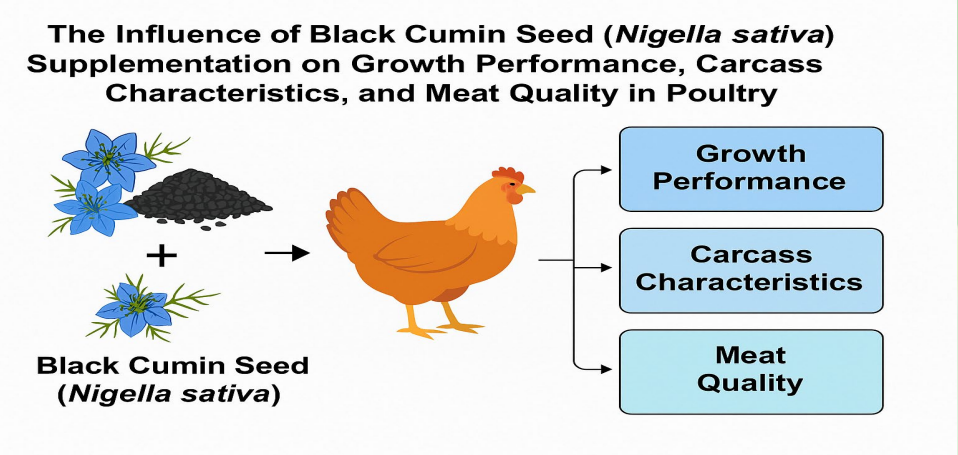
cholesterol reduction remains unclear, though it is hypothesized that N. sativa inhibits de novo cholesterol synthesis or lowers serum cholesterol levels.

Albumin quality has also been reported to improve with N. sativa supplementation, although its effect on yolk index appears to be negligible. Medicinal plants like N. sativa, known for their bioactive compounds, have the potential to support reproductive tissue health in laying poultry. For example, Boka et al. (2014) demonstrated that black cumin seed supplementation (1–3%) did not significantly affect laying rate or yolk cholesterol but positively influenced intestinal E. coli counts, blood biochemistry, and immune parameters. At doses above 2%, enhancements in egg production, weight, and shell strength were observed. On the other hand, Yalçin et al. (2012) reported a significant reduction in egg weight following N. sativa supplementation, with no notable changes in shell thickness, egg index, albumen height, or Haugh unit. Similarly, studies by Aydin et al. (2008) and Szczerbińska et al. (2012) found no effects on the live weight of hens.

Other researchers have highlighted the favorable influence of N. sativa on overall hen performance and egg quality parameters. Rich in unsaturated fatty acids like linoleic and oleic acids, black cumin seed inclusion up to 15 g/kg has been associated with improvements in egg weight, cholesterol levels, and yolk fatty acid composition. Bölükbaşi et al. (2009) confirmed that N. sativa oil can reduce intestinal E. coli, although its administration at 3 mg/kg may adversely affect the Haugh unit. In Aydin et al. (2008) trial, laying hens fed 3% black cumin seeds produced more eggs compared to controls, and eggs from hens fed 2–3% black cumin exhibited superior shell thickness and strength. Additionally, eggs from these groups showed a significant reduction in cholesterol content. As dietary fatty acid composition plays a key role in modifying egg lipid profiles, N. sativa proves to be a promising feed additive. Elkin et al. (1993) previously noted a cholesterol reduction from 30% to 20% through dietary modification without compromising egg weight. Supporting these findings, Hossain et al. found that dietary supplementation with 1.5%–2% black cumin significantly decreased yolk cholesterol without adverse effects on egg production or weight. Overall, evidence suggests that black cumin can positively influence various aspects of egg quality and production, although inconsistencies across studies highlight the need for further controlled investigations.

Optimal Inclusion Levels and Safety

In poultry nutrition, determining the optimal inclusion levels of additives like Black Cumin Seed (*Nigella sativa*) is crucial to maximizing their benefits while ensuring safety. Research on *Nigella sativa* supplementation in poultry diets suggests that inclusion levels typically range from 0.5% to 2%, depending on the desired outcomes and specific poultry species. These levels are generally considered safe and effective, providing significant improvements in growth performance, carcass characteristics, and meat quality without compromising feed intake or bird health. At lower inclusion levels (0.5% - 1%), Black Cumin Seed supplementation tends to offer benefits without adversely affecting feed palatability, while higher inclusion levels (1% - 2%) may enhance performance but could lead to reduced palatability or even potential negative effects if overused. Excessive inclusion can result in undesirable outcomes such as digestive disturbances, reduced feed consumption, or toxicity from exceeding safe nutrient thresholds (Asghar et al., 2022). Therefore, ensuring proper formulation of poultry diets with Black Cumin Seed is essential to achieve the desired effects on growth and meat quality without compromising safety. This requires careful calculation of inclusion levels based on the birds' age, growth stage, and environmental factors. Formulating diets with the appropriate balance, along with considering the bioavailability of the active compounds in *Nigella sativa*, ensures that the supplementation promotes optimal performance. Adhering to regulatory guidelines and safety protocols set by authorities like the FDA or EFSA is also critical in determining safe inclusion levels. In conclusion, optimizing the inclusion levels of Black Cumin Seed in poultry diets is key to improving growth performance, carcass traits, and meat quality while maintaining bird health and productivity.



This graphical abstract illustrates the impact of dietary supplementation with *Nigella sativa* (black cumin seed) on poultry performance, carcass characteristics, and meat quality. The diagram highlights the functional bioactive compounds of *Nigella sativa* and their physiological roles in enhancing digestion, immunity, and antioxidant status. These effects collectively contribute to improved growth performance, better feed efficiency, enhanced carcass yield, and superior meat quality in poultry production systems.

Challenges and Future Perspectives

Despite the well-documented benefits of *Nigella sativa* supplementation in poultry nutrition, several challenges continue to limit its widespread and standardized use in commercial production systems. One of the primary concerns is the lack of standardization in the active compounds, such as thymoquinone, which can vary significantly between different seed sources and extraction methods. This variability makes it difficult to ensure consistent efficacy across studies and applications. Additionally, geographic and environmental factors play a significant role in influencing seed quality, composition, and potency, further contributing to inconsistencies in performance outcomes. Another practical challenge is the cost-effectiveness of *Nigella sativa* supplementation at a commercial scale, particularly when high-quality or processed forms such as oils or extracts are used. These issues highlight the need for continued research and innovation in this area. Future studies should explore advanced delivery systems, such as nano-formulations or encapsulated extracts, to improve the bioavailability and stability of active compounds in the digestive tract. Moreover, the potential synergistic effects of combining *Nigella sativa* with other feed additives such as probiotics, enzymes, or other phytogenics should be investigated to enhance overall efficacy and reduce costs. In addition, molecular and genetic expression studies are essential to gaining deeper insight into the metabolic and physiological mechanisms through which *Nigella sativa* exerts its effects on growth performance and meat quality. Such research could pave the way for precision feeding strategies and the development of optimized formulations tailored to specific production goals. Overall, addressing these challenges through targeted research and innovation will be key to fully realizing the potential of *Nigella sativa* in modern poultry production.

Conclusion

In conclusion, *Nigella sativa* represents a highly promising natural feed additive with substantial potential to enhance poultry growth performance, carcass yield, meat quality, and overall health status. Its rich profile of bioactive compounds, particularly thymoquinone, contributes to its antimicrobial, antioxidant, immunomodulatory, and growth-promoting effects, positioning it as a compelling alternative to synthetic growth promoters. The multifaceted benefits observed across various studies highlight its role in improving not only production efficiency but also the quality and safety of poultry products. However, for *Nigella sativa* to gain wider acceptance in commercial poultry production, key challenges such as the standardization of active constituents, variability in seed quality, and cost-effective inclusion strategies must be addressed. Continued research focusing on improved formulations, such as nano-delivery systems and synergistic combinations with other phytogenics or probiotics, will be crucial in optimizing its efficacy. Ultimately, with proper standardization and strategic application, *Nigella sativa* holds strong potential to become an integral component of sustainable and health-oriented poultry nutrition programs.

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ID: 775

Farklı Yetiştirme Sistemlerinde Barındırılan Atak-S Erkek Civcivlerinin Et Kalite Özellikleri

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Özet

Bu çalışmada, yumurtacı bir hat olan Atak-S yumurtacı hibritlerin, cinsiyet ayrımı yapılarak itlaf edilen erkek civcivlerinin kapalı ve serbest (free range) yetiştirme sistemlerinde et kalitesi incelenmiştir. Her muamele gurubunda 3 tekerrür kullanılmış, her tekerrürde 28 adet muamele başına 84 adet, toplam 168 adet civciv kullanılmıştır. Kapalı yetiştirme sistemi (KYS) ve serbest yetiştirme sistemi (SYS) muamele guruplarında civcivler, kümeste yer bölmelerinde (3,7 civciv/m^2) büyütülmüştür. SKS muamele grubu için ise, kapalı bölmelere ek olarak yonca ekili açık alanda 3. haftadan itibaren civcivlere serbest dolaşma ve otlanma (0,9 civciv/m^2) imkânı verilmiştir. Çalışma, Kahramanmaraş Sütçü İmam Üniversitesi, Hayvansal Üretim Uygulama ve Araştırma Merkezinde 12 hafta süre ile yürütülmüştür. Deneme boyunca tüm civcivler aynı yemlerle sınırsız beslenmiştir. İki farklı yetiştirme sisteminde et kalitesi incelenen Atak-S erkek civcvilerinin göğüs ve but etlerinde ham kül, protein, nem, su tutma kapasitesi, yağ, Renk (L, A, B) Hue, Chroma, ΔE, kolesterol ve yağ asitleri kompozisyonu karşılaştırılmıştır. SYS ve KYS'nin but ve göğüs eti nem değerleri, su tutma kapasitesi, yağ oranı, renk L, renk A, renk B, Hue değeri, Croma değeri ve ΔE üzerine etkisi önemsiz ($p>0,05$) bulunmuştur. SYS ve KYS'de ham kül değerleri arasında fark önemli ($p<0,05$) olarak hesaplanmış, but ve göğüs etlerinin ham kül değerleri arasındaki farkta önemli bulunmuştur ($p<0,01$). But ve göğüs eti protein içeriği, yetiştirme sistemlerinden önemli derecede ($p<0,01$) etkilenmiştir. But ve göğüs eti protein içerikleri birbirlerinden farklı bulunurken ($p<0,01$) yetiştirme sistemleri ile et bölgesi arasında interaksiyona rastlanmamıştır($p>0,05$). But ve göğüs eti kolesterol içeriği de yetiştirme sistemlerinden önemli derecede ($p<0,01$) etkilenmiştir. But ve göğüs etlerinin kolesterol değeri arasındaki fark ta önemli bulunurken ($p<0,01$) yetiştirme sistemleri ile et bölgesi arasında interaksiyona rastlanmamıştır. Yağ asitleri kompozisyonları bakımından yetiştirme sistemleri arasındaki fark ise bazı yağ asitlerinde önemli bulunurken bazıları önemsiz bulunmuştur.

Anahtar kelimeler: Yetiştirme sistemi, Atak-S, Et kalitesi

ID: 776

Yavaş Gelişen Hubbard Red JA57 Etlik Piliçlerinin Farklı Yetiştirme Sistemlerinde Et Kalite Özellikleri

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Özet

Bu çalışmada, yavaş gelişen karışık cinsiyette Hubbard Red JA57 etlik piliç genotipi, kapalı ve serbest (free range) yetiştirme sistemlerinde incelenmiştir. Çalışma, Kahramanmaraş Sütçü İmam Üniversitesi, Hayvansal Üretim Uygulama ve Araştırma Merkezinde 12 hafta süre ile yürütülmüştür. Kapalı yetiştirme sistemi (KYS) ve serbest yetiştirme sistemi (SKS) muamele guruplarında civcivler, kümeste yer bölmelerinde (3,7 civciv/m2) büyütülmüştür. SKS muamele grubu için ise, aynı ölçülerde kapalı bölmelere ek olarak yonca ekili açık alanda 3. haftadan itibaren civcivlere serbest dolaşma ve otlanma (0,9 civciv/m2) imkânı verilmiştir. Her tekerrürde 28 adet civciv muamele başına 84, toplam 168 civciv her muamelede 3 tekerrür kullanılmıştır. Deneme boyunca tüm civcivler aynı yemlerle sınırsız beslenmiştir. İki farklı genotipin iki farklı yetiştirme sisteminde; et kalitesi incelenmiştir. Göğüs ve but etlerinde ham kül, protein, nem, su tutma kapasitesi, yağ, Renk (L, A, B) Hue, Chroma, ΔE, kolesterol ve yağ asitleri kompozisyonları karşılaştırılmıştır. Çalışmada; Hubbard Red JA57 piliçlerinin but ve göğüs etlerinde yetiştirme sistemleri arasındaki fark; ham kül, su tutma kapasitesi, yağ içeriği, renk değerleri ve kolesterol bakımından önemsiz ($p>0,05$) bulunurken, protein ($p<0,05$) ve nem ($p<0,01$) bakımından önemli bulunmuştur. Yağ asitleri kompozisyonları bakımından yetiştirme sistemleri arasındaki fark ise bazı yağ asitlerinde önemli bulunurken bazıları önemsiz bulunmuştur. Yetiştirme sistemleri ile cinsiyet ve yetiştirme sistemleri ile et bölgesi arasında interaksiyon ham kül, protein, nem değeri, su tutma kapasitesi, yağ, Renk (L,A,B), HUE değerleri, CHROMA, ΔE, Kolesterol önemsiz bulunurken, cinsiyet ile et bölgesi arasında interaksiyon sadece ham kül değerinde önemli ($p<0,05$) bulunurken diğer özelliklerde yine önemsiz bulunmuştur.

Anahtar kelimeler: Yetiştirme sistemi, Hubbard Red JA57, Et kalitesi

ID: 777

Sustainability and Environmental Footprints of AI-Integrated Agrifood Production Systems

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Abstract
Global food systems are facing challenges in meeting the rising demand for food while also reducing their environmental impact, including carbon and water footprints. Artificial intelligence (AI) offers promising solutions to improve efficiency, effectiveness, and resilience throughout the food supply chain. However, the use of AI in food production, particularly in advanced industrial settings such as Industry 4.0 and 5.0, also presents its own environmental and social challenges. This study examines the potential benefits of AI in creating a sustainable food system, including better resource use, less waste, improved water efficiency, and enhanced crop protection. It also considers the significant energy needed to train and operate AI systems. To ensure AI-based technologies truly support sustainability in food production, we need a balanced approach that includes fair access, responsible resource management, and integrating AI with other sustainable agricultural practices. Future efforts should focus on making AI tools easier to use for a wider audience, implementing strong governance rules, and aligning AI advancements with environmental, economic, and social impacts. By preventing these challenges, AI can be used to develop a more efficient, resilient, and environmentally friendly food resource system, contributing to global sustainability goals.
Keywords: Sustainability, environmental footprints, carbon and water footprints, AI-integrated food production, zero waste and water efficiency

Introduction

The integration of AI into agrifood production systems presents a dual narrative regarding sustainability and environmental footprints. While AI offers substantial promise in optimizing resource utilization, minimizing waste, and enhancing the precision of agricultural practices – thereby potentially reducing the environmental burden associated with conventional farming (Shamshiri et al., 2018; Hussain et al., 2024). The development and deployment of AI technologies themselves carry inherent environmental and social costs that necessitate careful consideration (Rolnick et al., 2019). A comprehensive understanding of the sustainability implications of AI in agrifood requires a nuanced evaluation that encompasses both the benefits derived from its application and the environmental and ethical considerations of its implementation (van Es and Woodard, 2017). AI-driven solutions in agriculture, such as precision farming techniques, have demonstrated the capacity to optimize the application of water, fertilizers, and pesticides, leading to significant reductions in resource consumption and environmental pollution (Shamshiri et al., 2018; Hussain et al., 2024). Furthermore, AI applications in monitoring crop health, predicting yields, and managing livestock can contribute to increased efficiency and reduced waste across the food production chain (Kamilaris et al., 2018; Wolfert et al., 2017). These advancements align with the goals of sustainable agriculture by enhancing productivity while minimizing negative ecological impacts. However, the sustainability benefits of AI integration must be weighed against the environmental footprint associated with AI technologies, including the energy consumption for training complex models and the resource demands for hardware production and data storage (Rolnick et al., 2019).

Addressing the sustainability and environmental footprints of AI-integrated agrifood systems requires a holistic approach that considers the entire lifecycle of both the AI technologies and the agricultural practices they enable. Future research and development should prioritize energy-efficient AI algorithms, the use of low-carbon infrastructure for AI deployment, and the establishment of ethical and environmentally responsible design principles (Rolnick et al., 2019). Furthermore, comprehensive life cycle assessments (LCAs) are needed to quantify the environmental impacts of AI in agriculture, from the manufacturing of sensors and AI hardware to the energy used in data processing and the disposal of obsolete equipment. By adopting a balanced perspective that maximizes the sustainability benefits of AI while mitigating its potential environmental and social costs, the agrifood sector can move towards a more resilient and environmentally sound future (Ahmed and Shakoor, 2025). This paper explores the potential of AI to revolutionize agrifood production for enhanced sustainability, resource optimization, waste reduction, and crop protection, while also addressing the associated environmental and social challenges and outlining future directions for accessible, governed, and impactful AI integration.

The Challenge of Global Food Systems

Global food systems today face a complex set of challenges that intersect with environmental sustainability, socio-economic equity, and political governance. As the global population continues to grow, current agricultural practices are increasingly being scrutinized for their impact on natural resources and their contribution to climate change. Feeding an estimated 9.7 billion people by 2050 requires a food systems transformation that not only ensures food security but also addresses sustainability and equity. Traditional and intensive agricultural practices have been reported to lead to biodiversity loss, soil degradation, and water resource depletion (Godfray et al., 2010; Tilman et al., 2011). These challenges call for an integrated approach that simultaneously addresses production efficiency and ecosystem protection.

One of the key challenges is inadequate food distribution. Although global food production is sufficient to feed the entire population, more than 828 million people were reported to be undernourished in 2021 (FAO, 2022). At the same time, food waste remains a widespread problem. Approximately one-third of all food produced globally is lost or wasted each year (Gustavsson et al., 2011). In addition to these problems, market volatility, trade restrictions and economic volatility also contribute to difficulties in accessing food. Foley et al. (2011) reported that innovative policy measures and collaborative management models that promote food supply are needed. Adaptive strategies such as climate-smart agriculture, improved infrastructure and sustainable land use should be prioritized to build resilience to environmental shocks (Wheeler and von Braun, 2013). Transforming the global food system requires a holistic approach that integrates environmental sustainability, economic viability and social justice. As the EAT-Lancet Commission stated, “a global transformation of the food system is urgently needed” to protect both human and planetary health (Willett et al., 2019). To overcome the multidimensional challenges of feeding the world sustainably, international collaborative efforts based on science and equity will be crucial.

The Promise of Artificial Intelligence in Agrifood Production

AI holds transformative potential for the agrifood sector, promising increased efficiency, sustainability, and resilience in food production systems. As global agriculture faces escalating pressures due to climate change, labor shortages, and the need for more precise resource management, AI-driven technologies are emerging as critical tools to address these challenges. According to Kamilaris et al. (2018), AI applications in agriculture including machine learning, computer vision, and robotics are facilitating more accurate crop monitoring, yield prediction, pest detection, and autonomous machinery operation, thus enabling data-driven decision-making at unprecedented scales.

One of the most significant contributions of AI is its role in precision agriculture. AI-powered platforms analyze large datasets from satellites, drones, and IoT sensors to provide real-time insights on soil conditions, crop health, and weather patterns. These insights allow for targeted interventions that minimize input waste and enhance productivity. For instance, Liakos et al. (2018) highlight the use of machine learning algorithms in predicting crop yields and optimizing irrigation, which not only conserves water but also reduces the environmental footprint of agricultural activities. In livestock farming, AI systems are employed to monitor animal behavior and health, improving welfare and early disease detection (Wolfert et al., 2017). Despite these advancements, the integration of AI in agrifood systems is not without limitations. Challenges such as high initial costs, lack of digital infrastructure in rural areas, and concerns over data privacy and ownership remain significant barriers to widespread adoption. Moreover, the ethical implications of AI deployment especially in smallholder farming contexts demand careful consideration to ensure inclusivity and equity. As van Es and Woodard (2017) suggest, the development of AI solutions should be accompanied by policies that support technological access and capacity-building, particularly in developing regions.

Sustainability Benefits of AI Integration

The integration of AI across sectors has shown tremendous promise in enhancing sustainability by optimizing resource use, minimizing waste, and supporting climate adaptation strategies. AI technologies facilitate real-time monitoring, predictive analysis, and intelligent automation that collectively contribute to more sustainable systems in energy, agriculture, transportation, and urban planning. AI can be a powerful tool for mitigating climate change if developed and implemented responsibly, particularly through applications such as energy optimization, precision agriculture, and smart logistics (Rolnick et al., 2019). In the energy sector, AI enables significant efficiency gains by predicting demand and managing supply in real time. Smart grids powered by AI dynamically adjust electricity flow, more effectively integrate renewable energy sources, and reduce transmission losses (IEA, 2021). For example, Google’s DeepMind successfully reduced data center cooling energy usage by 40% using AI-based control systems and demonstrated the scalability of AI for sustainable infrastructure management (Evans and Gao, 2016). Such applications not only reduce carbon footprints but also promote cost-effective energy practices.

AI in agriculture supports sustainable practices by enabling precision farming that reduces water, fertilizer, and pesticide use. Machine learning models can predict crop yields, detect disease outbreaks, and recommend site-specific treatments that maintain productivity while reducing environmental impacts (Shamshiri et al., 2018). In

sustainable agriculture, AI contributes to the efficient management of water, fertilizer, and pesticides through precision farming techniques. These advances not only increase crop yields but also minimize environmental degradation. It has been found that irrigation planning systems based on machine learning can reduce water usage by up to 30% without compromising productivity (Hussain et al., 2024). Despite its potential, the sustainability of AI must also be addressed, particularly in terms of energy consumption associated with model training and data storage. Sustainable AI development requires the use of energy-efficient algorithms, low-carbon infrastructure, and policies that prioritize ethical and environmentally responsible design.

Resource Use Optimization through AI

AI transforms resource optimization in cloud computing and software systems, increasing efficiency, scalability, and cost-effectiveness. AI techniques such as machine learning (ML), deep learning (DL), and reinforcement learning (RL) offer powerful tools for dynamic resource allocation, workload prediction, and cost management. For example, Artamonov and Balych (2024) state that neural networks provide high accuracy in resource acquisition and response times, improving data center performance by 20%, especially in cloud infrastructures. These systems prevent unnecessary consumption by distributing resources such as processors, memory, and storage according to real-time needs. Rao (2023) emphasizes that AI-based solutions reduce energy waste by up to 15%, especially in large-scale cloud platforms. This is a critical development in terms of both economic and environmental sustainability. Deep learning models, especially Convolutional Neural Networks (CNN) and Long Short-Term Memory (LSTM) networks, stand out in energy efficiency and resource management. Kristian et al. (2024) show that LSTM models provide 90% accuracy in workload predictions based on time series data, thus reducing energy consumption in data centers by 12%. For example, in a cloud-based software system, LSTM networks automatically adjust server capacity by predicting user demands, thus reducing both costs and carbon footprint. Similarly, CNNs optimize resource usage in infrastructure monitoring systems that require visual data analysis (e.g., server temperature control with thermal cameras). However, the high computational requirements of these models are a disadvantage. Reinforcement learning (RL) stands out as another important AI technique in terms of cost management and flexibility. Kumar and Gore (2024) showed that an RL-based system dynamically optimized resource allocation in cloud environments, reducing operating costs by 25% and reducing service outages by 30%. RL enabled the system to learn through trial and error, enabling it to quickly adapt to variable workloads. For example, in an e-commerce platform, RL instantly scaled server capacity against sudden demand increases during holiday seasons. Artamonov and Balych (2024), state that such systems are 40% more flexible than traditional methods, especially in hybrid cloud architecture. This flexibility perfectly suits the dynamic nature of cloud computing. While AI-based solutions revolutionize resource optimization, they also present some challenges. Rao (2023) lists high initial costs, data privacy concerns, and a lack of expert personnel as the main obstacles to the widespread adoption of AI. Furthermore, Kristian et al. (2024) emphasize that the energy consumption used in training complex deep learning models may conflict with sustainability goals. To overcome these problems, open-source AI frameworks (e.g., TensorFlow, PyTorch), lightweight models, and energy-efficient algorithms are being developed.

Waste Reduction and Improved Water Efficiency with AI

AI is contributing to sustainability goals by revolutionizing waste management and water efficiency. AI technologies such as machine learning and artificial neural networks have optimized waste separation and resource recovery processes, increasing recycling efficiency by 15% and reducing operational costs by 20% (Li Wei Ming et al., 2024). In Singapore, in particular, AI-powered waste management systems have increased recycling rates by 25% (Hernandez et al., 2024). These innovations reduce the amount of waste going to landfills, preventing environmental pollution and supporting the conservation of water resources. Real-time data analytics of AI transform waste management into a more efficient and environmentally friendly process. AI applications in agriculture reduce water use by 30% and increase crop yields (Hernandez et al., 2024). AI-based systems analyze sensor data to optimize irrigation processes and ensure targeted use of water. This is an important step in combating global water scarcity, as 1.1 billion people worldwide lack access to clean water. In addition, the role of AI in agricultural waste management reduces soil and water pollution by facilitating the recycling of organic waste. However, challenges such as infrastructure limitations and the need for specialized personnel must be overcome for these technologies to become widespread. In wastewater treatment processes, AI increases the potential for water reuse and increases efficiency. AI systems integrated with the Internet of Things (IoT) determine the suitability of water for irrigation by monitoring water quality parameters (Narayanan et al., 2023). AI models exhibit high accuracy (R^2 value between 0.64 and 1.00) in predicting the removal efficiency of pollutants and effectively monitor water quality in wastewater treatment plants (Nagpal et al., 2024). These systems support environmental sustainability by reducing energy consumption and optimizing treatment processes. The success of AI in this area both saves water and contributes to global water management policies.

AI-Driven Crop Protection Solutions

AI and ML revolutionize crop protection strategies, enhance precision farming, pest management, and harvest optimization. These technologies enable real-time monitoring, predictive analytics, and data-driven decision-making, improving resource efficiency and reducing environmental impacts (Gustavo A. Mesías-Ruiz et al., 2023). AI applications in agriculture include big data analysis, pest and disease forewarning models, and ICT-based crop advisory systems (M. Pratheepa et al., 2023). Advanced crop protection techniques incorporate innovative chemical formulations, bio-PPPs, and AI-driven disease detection systems (A. Balafoutis et al., 2021). Integration with IoT and autonomous farming equipment further enhances productivity and minimizes labor costs (Danish Gul & Rizwan-ul-Zama Banday, 2024). However, data quality, infrastructure limitations, and implementation costs persist, particularly for small-scale farmers in developing regions (Danish Gul & Rizwan-ul-Zama Banday, 2024).

Environmental and Social Challenges of AI Implementation

AI is a general term used for a wide range of machine intelligence systems that can copy people's behavior. AI and Big Data have emerged as the defining features of the fourth industrial Revolution (IR). AI has developed tools. Due to innovation, the study of IR, AI and their environmental impact is still in the early stages of research (Adnan et al., 2024). Human-caused climate change and the degradation of our natural environment are critical problems. Advanced technologies such as AI offer the potential for the development of solutions. Machines that learn by acquiring information and perform human-like tasks can help humans reduce their intensive use of natural resources and improve environmental governance for more sustainable living (Taghikhah et al., 2022). The application of AI in environmental monitoring offers accurate disaster forecasts, pollution source detection, and comprehensive air and water quality monitoring (Olawade et al., 2024).Actually, the use of AI technology in environmental management, especially in terms of pollution, has emerged as a remarkable breakthrough in transforming our methodology for monitoring the environment. It has been given many advantages not only for developing AI hardware that focuses on sustainability by reducing energy use and using environmentally friendly materials, but also for improving of climate prediction models and environmental monitoring systems using AI (Adnan et al., 2024). In the other words, with the global energy sector under increasing pressure to support sustainability, the function of AI in improving Environmental, Social and Governance (ESG) performance is of great interest (Wang and Zhang, 2025). Carbon capture, utilization and storage (CCUS) are emerging as a promising solution to reduce global CO_2 emissions from the industrial and energy sectors (Elaouzy and Zaabout, 2025).

The social and environmental effects of developing productive AI. These include environmental challenges such as energy and resource consumption, and social issues such as working conditions and accessibility gaps, which highlight the systemic resource demands and socio-economic consequences of productive AI (Hosseini et al., 2025). As organizations continue to embrace the use of AI systems, it is very important to ensure that these AI systems can be trusted. However, there is still a significant gap between AI research and its application in real-world applications (Cousineau et al., 2024). Firstly, companies should prioritize integrating AI technologies into their ESG strategies by promoting a synergy between green innovation and AI through investments in AI-oriented sustainability solutions and cross-functional cooperation. Secondly, policymakers should provide specific support and incentives such as financial subsidies, tax incentives and technical assistance. In addition, differentiated policy measures are required to meet the specific needs of different types of enterprises, direct kits to pilot large-scale AI-oriented ESG projects, and support SMEs through capacity building and specialized AI tools. Finally, strengthening corporate ESG information disclosure and oversight mechanisms, including standard reporting frameworks and independent audits, is crucial to ensure transparency and accountability (Weng et al., 2025).

Towards Sustainable AI in Food Production: A Balanced Approach

The growing universal population and the growing demand for food are putting significant pressure on the global agricultural system to increase production. However, the expansion of agricultural land often comes at the expense of wildlife habitats, escalates human-wildlife conflicts as crops are damaged by animals, and threatens food security. In addition, the use of unsustainable deterrent methods can harm biodiversity. Current crop protection methods fall short of supporting sustainable agriculture goals (Abed et al.,2025). Agriculture and the food system are facing challenges related to climate change, biodiversity loss, agricultural pollution and food security. Food security at the international and national levels needs to be developed in an environmentally and resource-friendly way. Digitalization and AI provide opportunities to overcome these challenges and facilitate the transformation of agriculture and the food value chain (Wepner et al., 2025). One study used image-based experimental methods to explore the intersection of sustainability, gastronomic tourism and AI, with a focus on promoting ‘climate-conscious food’. This term refered to food produced with environmentally friendly practices. Despite the benefits of climate-conscious foods for individuals, the environment and local tourism, their adoption remained limited. This conceptualized research on visual information processing consists of two studies that use bottom-up and top-down processing. It confirmed that the type of content in the images generated by AI, especially the “Food

Presentation" versus the "Preparation Process", significantly affected consumers' perceptions of food quality and purchasing intentions (Chan et al., 2025). Indeed, the widespread use of chemical fertilizers on small farms has helped to increase crop yields, support food security and economic growth. However, recent studies have showed that these fertilizers are often used inefficiently and inconsistently. This leads to environmental damage, unstable soil nutrients and low-quality food production (Pandian et al., 2024). Infrastructure limitations, high implementation costs and data privacy concerns must be resolved to promote fair access and widespread adoption. Standardization of interoperability and quality control protocols is also critical to ensure accurate measurement and reporting of emissions. Future research should further refine ML models to address local variability in climate, soil, and farm practices, while exploring collaborative frameworks that protect data privacy (e.g., unified learning). Moreover, integrating policy incentives, capacity building programs and stakeholder collaborations can accelerate the use of IoT and Big Data tools in real-world agricultural environments. By addressing these issues, the agricultural sector can benefit from digital innovations to reduce its carbon footprint, increase resilience to climate change, and advance global sustainability goals (Ahmed and Shakoor, 2025). In the context of greenhouse agriculture, the integration of AI is being evaluated in terms of its potential to improve sustainability and crop production efficiency (Hoseinzadeh and Garcia, 2024). The relationship between developments in Industry 4.0 technology such as AI and their impact on the earth, the environment, humans and biological ecosystems needs to be taken into account more consideration. One article addressed the challenge of monitoring the indicators of the 17 SDGs by taking advantage of Industry 5.0 developments. It offered practical verification of the framework through use cases in energy and water management. The results showed how the framework can improve the sensitivity, transparency and scalability of SDG monitoring while providing useful information to stakeholders. (Hassan et al., 2025).

Future Directions: Accessibility, Governance, and Impact Alignment

Future directions necessitate a focus on critical areas such as accessibility, governance, and impact alignment with the widespread adoption of AI and related technologies. Particularly, with the increasing prevalence of AI-driven solutions in environmental monitoring and sustainable agriculture practices, ensuring these technologies are accessible to all stakeholders is of paramount importance. As emphasized by Ahmed and Shakoor (2025), the effectiveness of Internet of Things (IoT), Big Data, and AI-based smart agriculture technologies in supporting sustainability hinges on their ease of adoption and implementation by farmers and other users in rural areas. Furthermore, as noted by Cousineau, Dara, and Chowdhury (2024), AI systems must be operated within a transparent and accountable governance framework, considering the challenges and opportunities faced by AI developers in creating trustworthy AI applications. The meticulous evaluation of the environmental and socioeconomic impacts of AI technologies and their alignment with sustainability principles is also a priority among future directions. The research by Hosseini, Gao, and Vivas-Valencia (2025) underscores the need for a comprehensive analysis of the social and environmental impacts of generative AI. Similarly, Wang and Zhang (2025) highlight the importance of innovation, collaboration, and proactive sustainability strategies to enhance the environmental, social, and governance performance of AI-enabled supply chains in the energy sector. In this context, minimizing the environmental footprint, promoting social justice, and establishing robust governance mechanisms are critical considerations in the development and implementation of AI applications. Lastly, an interdisciplinary approach is essential for aligning AI technologies with sustainable development goals. The study by Pandian et al. (2024) emphasizes the significance of synergistic conservation strategies that address the interconnections between soil health, food security, and human health. In this regard, collaboration among experts from various disciplines and the adoption of a holistic perspective towards sustainability goals are necessary during the development and implementation of AI applications. As indicated by Wepner et al. (2025), the exploration of digitalization's impacts on the sustainability of agri-food systems through diverse scenarios will guide the effective utilization of AI and digital technologies.

Conclusion

The global food system faces significant interconnected challenges spanning environmental sustainability, socio-economic equity, and political governance, demanding a transformative shift to feed a growing population responsibly. AI emerges as a powerful catalyst in this transformation, offering promising solutions for enhanced efficiency, sustainability, and resilience across the agrifood value chain. From precision agriculture optimizing resource use to AI-driven crop protection and waste reduction, the integration of AI technologies presents substantial benefits for environmental stewardship and resource management. However, the widespread and equitable adoption of AI in agrifood production is not without its hurdles. Issues such as high initial costs, infrastructure limitations, data privacy concerns, and the energy consumption of AI models themselves must be carefully addressed. Ensuring accessibility for smallholder farmers, establishing robust governance frameworks, and aligning AI development with broader sustainability principles are crucial for realizing the full potential of AI in creating a more sustainable and equitable food future. Moving forward, a balanced approach is essential. This involves fostering international collaboration, promoting open-source AI solutions, developing energy-efficient

algorithms, and implementing supportive policies that prioritize inclusivity and capacity building. Future research should focus on refining AI models for local contexts, exploring collaborative data governance frameworks, and integrating policy incentives to accelerate the adoption of sustainable AI practices in agriculture. Ultimately, by thoughtfully navigating the challenges and strategically leveraging the opportunities, AI can be a transformative force in building a global food system.

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Determination of Amino Acid Profile of Sea Bass Cooked in Microwave Oven

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Abstract

It is evident that fish and fish products constitute a significant dietary source of animal origin for humans, playing a crucial role in the human nutrition. These products are of esential importance in ensuring adequate and balanced nutrition. The nutritional value of fish is subject to variation depending on the species; however, it is widely considered to be an excellent source of protein. In addition, fish products contain significant levels of omega-3 and other fatty acids necessary for our body. The present research aimed to determine the amino acid profile and some quality parameters of sea bass cooked using microwave. While the average pH value of the sea bass fish used in the study was 6.39, their moisture content was determined as 73.58%. Additionally, fifteen different amino acids were examined in the study. The amino acid content of the sea bass samples was found to vary between 1.97 and 178.22 µg/g. Major amino acids were determined as lysine, glycine, glutamate, alanine, proline and phenylalanine.

Key Words: *Fish, microwave, sea bass, cooking, amino acid profile*

Introduction

It is an irrefutable fact that foods of animal origin (such as red meat, chicken and fish) are indispensable products of human nutrition. Notably, fish constitutes a significant protein and nutrient source, essential for maintaining a healthy diet (Savaş et al., 2021; Savaş et al., 2023; Borrull et al., 2025). The nutritional composition of fish and its products is subject to variation due to a number of factors, including species, genus, age and geographical location. As is well documented, fish products boast a highly sophisticated composition in terms of both macro and micro components. Notably, fish proteins are distinguished by their complete amino acid profile, which is indispensable for the protection and development of body tissues (Turan et al., 2006).

Türkiye has the potential to become a significant producer of fish products. The region's strategic positioning, encompassed by seas and boasting approximately 25 million hectares of arable land conducive to aquaculture, confers a series of substantial benefits. Sea bass (Dicentrarchus labrax), a highly regarded fish product, is one of the fish species produced and consumed in Turkey and the Mediterranean countries (Alpaslan and Baygar, 2009; Karahan, 2009).

The consumption of meat products is typically followed by a process of cooking. While the cooking process provides both flavour and aroma to meat and meat products, it also contributes to the production of a microbially consumable product. However, in addition to the loss of nutrients due to inadequate cooking conditions, there is also the formation of mutagenic and/or carcinogenic compounds (Savaş et al., 2021; Savaş et al., 2023).

A substantial number of epidemiological studies have been published which demonstrate the significant role that nutrients and dietary habits play in certain diseases to which the societies is exposed. Consequently, there is an increasing awareness of the necessity to adopt a more conscious approach to eating. In this context, the number of studies on fish with a high nutritional composition continues to increase. In the present study, the analysis of sea bass fish was conducted in accordance with a range of quality parameters and amino acid profiles, utilising a microwave oven as the primary analytical instrument.

Materials and Methods

The sea bass (Dicentrarchus labrax) used as raw material in the research were obtained from the fish market in Giresun province. Special care was taken to ensure that the weight and size of the purchased fish were similar.

Cooking process

Samples of fish were transferred to the laboratory in a refrigerated environment and then subjected to a meticulous cleaning process to remove any internal organs. The fish samples were divided into two parts and cooked in a

microwave oven (MD 211DG, Arçelik, Turkey) with skin for a duration of 14 minutes. No oil and spices were used during the cooking process.

Water content ve pH analysis

Water content and pH values of the samples were determined according to the methods of Gokalp et al. (2010).

Free Amino Acid Screening with LC-MS/MS

The extraction of free amino acids from the samples was conducted as follows: 0.5 g of each sample was homogenised with 40 ml of 0.1 M HCl solution. The homogenate was then stored at 4°C for a period of 12 hours. Subsequently, the samples were subjected to centrifugation (MR 23i, Thermo Fisher Scientific) at 10000 g for 50 minutes at 4°C. Following extraction, the samples were filtered through a PTFE filter (Isolab 0.45 um) and transferred to a capped vial (Antoine et al., 1999; Oz, 2018).

Analyses were performed using a combined system of liquid chromatography (Spark Holland) and tandem mass spectroscopy (AB SCIEX 4000 QTRAP). The conditions for chromatographic analysis were; a C18 type column (Inertsil ODS-3V 250 mm x 4.6 mm, 5 µm), injection volume 10 µL, flow rate 0.700 mL/min and column oven temperature 30°C.

Statistical analysis

The present study was conducted using a completely randomised design with three replicates. All the data were presented as the mean ± standard deviation of the mean.

Results and Discussion

The water and pH values of the sea bass (Dicentrarchus labrax) used as raw material in the research were determined as %73.58±0.79 and 6.39 ± 0.03, respectively. Indeed, a preponderance of studies conducted hitherto have yielded analogous results (Türkkan et al., 2008; Sumi et al., 2025).

The amino acid profile of sea bass samples subjected to microwave-based cooking techniques in the present study is outlined in Table 1. In the present study, the amino acid composition of sea bass samples was analysed. The amino acid content of the samples exhibited a range from 1.97 to 178.22 µg/g. Subsequent analysis of the results yielded the determination that the predominant amino acids were lysine, glycine, alanine, glutamate, methionine, leucine, isoleucine and phenylalanine. Similar studies have been conducted in the literature (Baki et al., 2015). Sumi et al. (2025) determined seventeen different amino acids in their study on cultured and wild sea bass and reported that the amino acid contents of the samples varied between 17.11 mg/g and 116.03 mg/g.

Table 1. Amino acid profile of sea bass fish samples

Amino acid profile	Sea bass (µg/g)
Lysine	29.93±0.96
Histidine	1.99±0.10
Glycine	178.22±4.92
Serine	2.07±0.18
Alanine	137.29±3.72
Glutamic acid	72.44±1.55
Cysteine	6.83±0.14
Aspartic acid	18.94±1.13
Proline	16.96±0.77
Methionine	91.06±1.90
Leucine	29.93±0.88
Isoleucine	18.68±0.12
Tyrosine	5.29±0.17
Phenylalanine	57.85±1.03
Tryptophan	1.97±0.06

Conclusion

It is evident that fish and fish products constitute a significant component of the human diet, representing a vital source of animal protein. As is well documented, fish products exhibit a rich fatty acid profile and constitute a significant protein source. Furthermore, it is a rich source of essential and non-essential amino acids. The present study investigates the amino acid profile of sea bass fish. In this study, the amino acid profile of sea bass was examined after cooking it using microwave and fifteen different amino acids were determined. The effect of cooking on the nutritional composition of meat and meat products is significant. Consequently, there is a necessity for further research to ascertain the most suitable cooking methods.

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Aflatoxins in Hazelnuts and Their Effects

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Abstract

Hazelnuts are considered a significant component of human nutrition. They occupy a significant position in the classification of nuts, particularly with regard to production and consumption volumes. The leading producers of this commodity include Turkey, Italy, Azerbaijan, Georgia and other countries. Hazelnuts are consumed raw and also processed into a wide variety of food products. However, a significant challenge for hazelnuts and their products is the presence of aflatoxins. Aflatoxin and its metabolites pose a significant risk to human health as carcinogenic substances. Sensitive and rapid detection and detoxification of aflatoxins is invaluable in food safety, environmental monitoring and risk assessment. Aflatoxins produced by *Aspergillus flavus* and *Aspergillus parasiticus* are among the most toxic mycotoxins. And the formation of these mycotoxins is affected by many parameters such as environmental environment, temperature, humidity. In this context, the current research has compiled the presence of aflatoxins in hazelnuts and their products, detoxification methods and their effects on human health.

Key Words: *Hazelnut, aflatoxins, detoxification, health, nuts*

Introduction

Nuts are a class of foodstuffs that are included in human nutrition and possess both nutritional content and functional properties. Hazelnut (*Corylus avellana* L.), which occupies a significant position in this food group, is distinguished as one of the most produced and consumed nuts globally. As it is known, hazelnut is a plant from the birch family and among the most important producers are Turkey, Italy, Georgia, Azerbaijan, USA and other countries. Hazelnuts can be consumed both raw and used as raw material in many areas, especially in the chocolate industry. On the other hand, mycotoxins have been identified as a fundamental factor contributing to significant quality issues in hazelnut products, which are characterised by their high content of bioactive components, fatty acids, and antioxidants (Zhao et al., 2023; Savaş, 2024b, Savaş, 2024a).



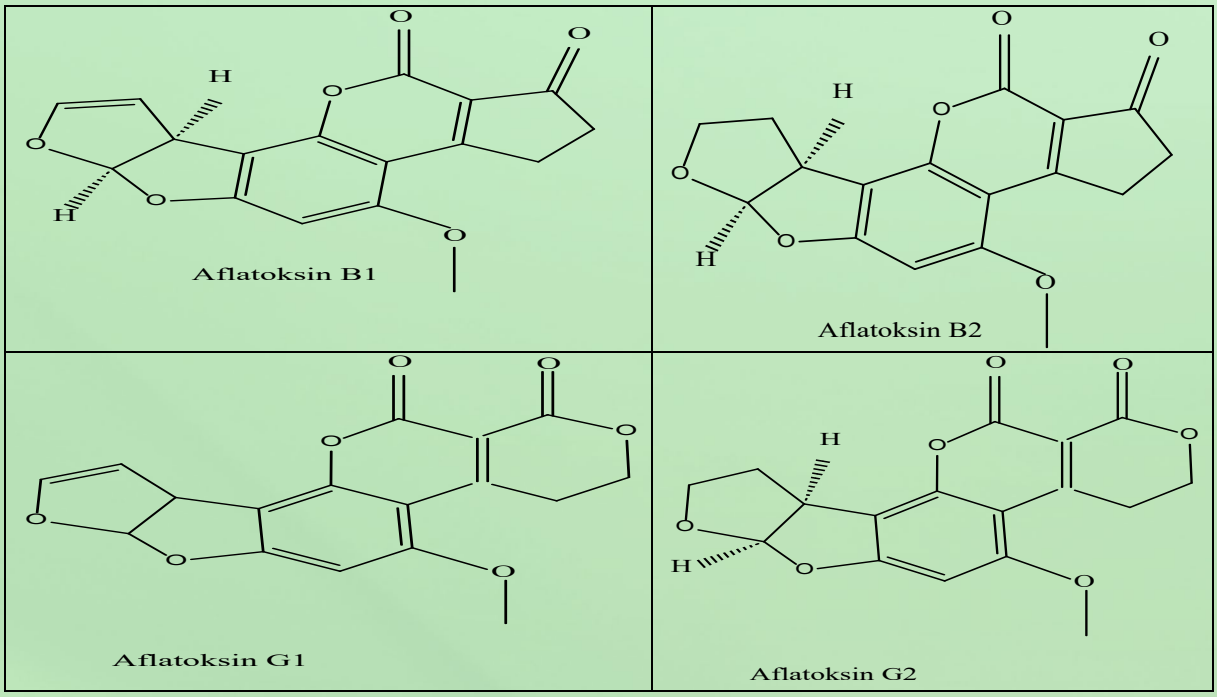
Figure 1. Hazelnut samples with and without aflatoxin

Mycotoxins are defined as secondary metabolites with the capacity to affect human health. To date, more than 400 mycotoxins have been identified, which have toxic effects on animals, including humans (Savaş, 2024; Pokoo-Aikins et al., 2024). The most well-known of these are aflatoxins (AFs), zearalenone (ZEA), deoxynivalenol (DON) and ochratoxin (OTA). Furthermore, these toxins have been observed to accumulate in the organs or tissues of animals upon ingestion, and consequently, they can be transferred to foods of animal origin(Juan et al.,

2019; Alaboudi et al., 2022). Especially among these mycotoxins, aflatoxins with difuran and coumarin skeletons are among the most toxic mycotoxin representatives(Yang and Wang, 2021; Kang and Zhao, 2025).

Aflatoxins, of which twenty types have been identified, are important toxins produced by *Aspergillus flavus* and *Aspergillus parasiticus*. The identification of aflatoxins is based on a combination of molecular differences, fluorescence properties under ultraviolet light, and chromatographic mobility (Catanante et al., 2016; Kang and Zhao, 2025). As has been demonstrated by numerous studies, the presence of aflatoxins has been identified in spices, nuts and fermented products, particularly in cereals. It has been asserted that the toxicity of aflatoxin B1 is significantly higher than that of potassium cyanide (10 times) and arsenic (68 times). Aflatoxin and its metabolites have been demonstrated to pose a significant risk to human health as carcinogens. Moreover, it is also stated that they have various effects such as hepatotoxic, genotoxic and mutagenic. (Kang and Zhao, 2025). However, aflatoxins, which are classified as hepatocarcinogens, are mostly stated to have uncertain effects on tissues other than the liver (Yang and Wang, 2021). In this context, Herzallah (2013) reported that aflatoxin B1 residues were detected in eggs and meat of chickens fed with aflatoxin B1-contaminated feed and egg production decreased. The chemical structures of the most common aflatoxins are presented in Figure 2.

Figure 2. Chemical structures of aflatoxin B1, B2, G1 and G2



The ingestion of aflatoxin-contaminated foodstuffs or animal products has been demonstrated to engender a range of health risks. The most prevalent methods of detoxification of aflatoxins are physical, chemical and biological. (Wang et al., 2025). Due to the thermal stability of aflatoxins, it is stated that AFB1 cannot be destroyed by normal cooking processes. However, various studies in the literature have reported that aflatoxins can be detoxified from different food products. For example, Wang et al. (2025) reported that AFB1 can be removed from peanut oil at different levels in their study. Şen et al. (2019) reported that cold plasma and gamma irradiation methods detoxify AFB1 at different levels in hazelnut samples. On the other hand, it has been revealed by various studies that aflatoxins can be detoxified. However, it is a fact that detoxification methods have various disadvantages in terms of high cost and side effects.

The impact of mycotoxins on human health has been elucidated through in vivo, in vitro and epidemiological studies. In particular, aflatoxins, which constitute one of the most significant toxic classes among mycotoxins, have been demonstrated to exert effects on reproduction and development, neurotoxicity, intestine and metabolism by in vivo, in vitro and epidemiological studies (Kousar et al., 2024; Wang et al., 2025). In this context, it is hypothesised that the consumption and formation conditions of foods containing aflatoxins should be prevented.

Conclusion

Nowadays, there is a growing interest in healthier, functional foods. However, various toxic compounds, including aflatoxins, may occur as a result of improper harvesting, storage, transport and applied processes. A review of the extant literature reveals numerous studies addressing the presence of aflatoxins in hazelnuts and various food groups. In particular, it is thought that the formation levels of aflatoxins should be at a minimum level due to their health effects and carcinogenicity, and more focus should be placed on control mechanisms and detoxification studies.

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ID: 789

Serbest ve Zenginleştirilmiş Kafes Sisteminin Yumurta Mineral Madde Ve Yağ Asitleri İçeriğine Etkisi

Mehmet Zahit DEMİR, Hasan ELEROĞLU

Özet

Bu araştırmada serbest ve zenginleştirilmiş kafes sisteminin yumurta mineral madde içeriğine etkisi üzerinde durulmuştur. Çalışma, zenginleştirilmiş kafes sistemi ve altlıklı yer sisteminde yetiştirilen Atak-S kahverengi yumurtacı hibritlerden elde edilen yumurtalar üzerinde yürütülmüştür. Toplanan yumurtaların Palmitik Asit (PA), Stearik Asit (SA), Oleik Asit (OA), Linoleik Asit (LA), α-Linoleik Asit (ALA) ve Miristik Asit (MA) içerikleri analiz edilmiş, yetiştirme sistemlerinin bu özellikler üzerine etkisi bulunmamıştır ($p>0,05$). Toplanan yumurtaların ağır metal içeriklerini belirlemek amacıyla Demir (FE), Bakır (CU), Çinko (ZN), Kurşun (PB), Kadmiyum (CD) ve Krom (CR) analizleri yapılmıştır. Yetiştirme sistemlerinin toplanan yumurtaların ağır metal içeriği üzerine etkisi bulunmamıştır ($p>0,05$). Yumurta kalitesinin artırılması yönünde yapılacak çalışmalara kaynak oluşturacak bu araştırma sonuçları dikkate alındığında, serbest gezinmeli sistem ve zenginleştirilmiş kafes sisteminde barındırmanın yumurta iç kalitesi üzerine farklılık meydana getirmediği dikkate alındığında, zenginleştirilmiş kafes sisteminin açık sisteme benzer yumurta iç kalitesine etkide bulunduğu sonucuna varılmaktadır. Ancak, bu araştırmada tek bir genotip dikkate alınmış olup, ileri çalışmalarda genotip farklılığının yetiştirme sistemleri ile birlikte alınmasında yarar vardır.

Anahtar Kelimeler: Yumurta kalitesi, serbest yumurta tavukçuluğu, kafeste tavukçuluğu, Yumurta İçeriği, Mineral Madde

ID: 790

Traceability in Food Logistics: From Farm to Fork

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Abstract

Traceability is an important cog in the machinery of modern food logistics systems for attaining the twin objectives of transparency, safety, and efficiency along the food supply chain. Traceability systems allow for real-time monitoring, verification, and response by stakeholders in food production and consumption, from farm to fork, to any issues concerning quality or safety. Thus, this study proposes investigating the traceability of food logistics and the ensuing role in food safety, compliance, and consumer trust. The main focus of the paper is on the structure and operation of traceability systems, resulting-from-technologies like barcoding, RFID, IoT devices, and blockchain applications. These technologies promote the tracing of food products through supply chain nodes: producers, processors, distributors, and retailers: while enabling faster corrective action. The analysis of the cases three from developed countries and three from emerging ones reveals best practices and widespread challenges in the adoption of traceability systems. The study also points to the increasing relevance of end-to-end visibility for sustainable and resilient food supply chains. With growing global trade in food and consumer awareness, traceability is no longer a regulatory requirement but also a strategic marketing tool to gain a competitive edge. Hence, the research elaborates that proper traceability improves accountability, risk management, and trust among stakeholders in food logistics operations. The study recommends investments in traceability technologies and alignment with regulations as critical for making food logistics systems evolve in today's increasingly complex global environment.

Key Words: *traceability, food logistics, supply chain, food safety, transparency, farm to fork*

ID: 432

Molecular Species Identification of Potato Golden Cyst Nematode (*Globodera rostochiensis*) Populations in Niğde Province

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Abstract

In this study, the species of Potato Cyst Nematode (PKN) populations taken from 38 locations where intensive potato cultivation is carried out in Niğde province were determined by molecular method. *Globodera rostochiensis* (Wollenweber, 1923) Skarbilovich, 1959, named as Golden cyst nematode, and *G. pallida* Stone, 1973 (Tylenchida: Heteroderidae), named as White cyst nematode, are species that cause serious yield losses in potato cultivation in our country and worldwide. *G. rostochiensis*, which was first detected in Bolu province in Turkey in 1985, was also detected in Niğde, Nevşehir, İzmir, and Afyon provinces in the following years. Accurate and rapid species identification is very important in resistant variety development studies, which is the most effective control strategy against *G. rostochiensis* and *G. pallida.* ITS5, PITSp4, PITSr3 primers were used to distinguish nematode species by molecular method. As a result of species identification, *G. pallida* was not detected and all samples were identified as *G. rostochiensis*.

***Key Words*:** Potato Cyst Nematode, Niğde, molecular diagnosis, potato.

Niğde İli Patates Altın Kist Nematodu (*Globodera rostochiensis*) Popülasyonlarının Moleküler Tür Teşhisi

Özet

Bu çalışmada Niğde ilinde yoğun patates yetiştiriciliği yapılan 38 lokasyondan alınan Patates Kist Nematodu (PKN) popülasyonlarında moleküler tür teşhisi yapılmıştır. Altın kist nematodu olarak isimlendirilen *Globodera rostochiensis* (Wollenweber, 1923) Skarbilovich, 1959 ve Beyaz kist nematodu olarak isimlendirilen *G. pallida* Stone, 1973 (Tylenchida: Heteroderidae), ülkemizde ve dünya çapında patates yetiştiriciliğinde ciddi verim kayıplarına neden olan türlerdir. Türkiye'de ilk kez 1985 yılında Bolu ilinde tespit edilen *G. rostochiensis* daha sonraki yıllarda Niğde, Nevşehir, İzmir, Afyon illerinde de saptanmıştır. *G. rostochiensis* ve *G. pallida'*ya karşı en etkili mücadele stratejisi olan dayanıklı çeşit geliştirme çalışmalarında doğru ve hızlı tür teşhisi yapılması oldukça önemlidir. Moleküler yöntemle nematod türlerini ayırmada ITS5, PITSp4, PITSr3 primerleri kullanılmıştır. Tür teşhisi sonucunda *G. pallida* tespit edilmemiş olup tüm örnekler *G. rostochiensis* olarak tanımlanmıştır.

***Anahtar Kelimeler*:** Patates Kist Nematodu, Niğde, moleküler teşhis, patates.

ID: 392

In Vitro Comparative Activities of Four Essential Oils on Mycelial Radial Growth of *Magnaporthe Oryzae* B.C. Couch, a Rice Blast Pathogen in Burkina Faso

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Abstract

Caused by *Magnaporthe oryzae* B.C. Couch, rice blast is considered as the main fungal disease in rice fields in Burkina Faso. Pure essential oils of *Cymbopogon schoenanthus, Ocimum americanum, Ocimum gratissimum* and *Lippia multiflora* were tested in vitro to assess the radial growth and inhibition rate of the fungus using the contact and fumigation methods. For each essential oil, five doses were developed: D2 (0.1 µl/ml), D4 (0.6 µl/ml), D6 (1.2 µl/ml), D8 (1.8 µl/ml) and D10 (2.4 µl/ml). In both tests, two synthetic fungicides namely mancozeb and azoxystrobin at recommended doses of 6.67 µl/ml and 3.33 µl/ml respectively, and an absolute control were used. The results showed that in the contact method, pure essential oils of *O. americanum, L. multiflora, C. schoenanthus* and *O. gratissimum* inhibited 100% of the mycelial radial growth of the fungus at doses D10 (2.4 µl/ml), D4 (0.6 µl/ml), D6 (1.2 µl/ml) and D4 (0.6 µl/ml) respectively. As for the fumigation method, oils of *O. americanum, L. multiflora, C. schoenanthus* and *O. gratissimum* inhibited mycelial radial growth of the fungus by 100% at doses D10 (2.4 µl/ml), D2 (0.3 µl/ml), D6 (1.2 µl/ml) and D8 (1.8 µl/ml) respectively. Mancozeb and azoxystrobin inhibited radial mycelial growth by 100% and 74.1% respectively. These essential oils can be used to control rice blast in the field. This will also reduce environmental pollution.

Key words : *Essential oils, Efficacy, Oriza sativa, Magnaporthe oryzae, Burkina Faso*

Introduction

Rice blast, caused by the fungus *Magnaporthe oryzae*, remains the most damaging fungal constraint to rice production, with damage that can cause yield losses of up to 100% if no protective measures are taken (Zhan *et al.,* 2018 ; Li *et al.,* 2019 ; Savary *et al.,* 2019 ; Kassankogno *et al.,* 2021). The use of chemicals such as tricyclazole to control M. oryzae has been successful in increasing yields (Moinina *et al.,* 2018). However, their application has numerous consequences for human and animal health and the environment. It is therefore necessary to use alternative control methods such as biological control through the use of biopesticides (Yarou *et al.,* 2017 ; Gamsore *et al.,* 2018 ; Toundou *et al.,* 2020). Studies have shown that essential oils possess insecticidal, bactericidal or fungicidal properties (Amarti *et al.,* 2010 ; Hamdani *et al.,* 2015). Also, other authors have shown that Lippia multiflora essential oil has strong antifungal activity, totally inhibiting the mycelial growth of Fusarum moniliforme and *Bipolaris oryzae* at 100 ppm and 400 ppm respectively (Tiendrebeogo *et al.,* 2017). However, the use of essential oils from aromatic plants for the control of M. oryzae remains largely unexplored. With this in mind, the present study was initiated to evaluate the *in vitro* efficacy of *Cymbopogon schoenanthus*, *Ocimum americanum*, *Lippia multiflora* and *Ocimum gratissimum* essential oils for the control of *M. oryzae*. Specifically, the aim is to evaluate the *in vitro* comparative activities of four essential oils on mycelial radial growth of *Magnaporthe oryzae* B.C. Couch, a rice blast pathogen in burkina faso.

Materials and methods

Fungal material

The fungal material used was *Magnaporthe oryzae* strain BF075 from rice leaves collected at the Farakô-Bâ site and isolated at INERA Farakô-Ba's phytopathology laboratory. The choice of this strain is justified by its virulence level (Kassankogno, 2016).

Essential oils

The essential oils of the *C. schoenanthus, O. americanum, L. multiflora* and *Ocimum gratissimum* aromatic plants used for the tests were extracted from the leafy twigs and used in pure without any combination.

Effects of essential oils on mycelial growth of M. oryzae on PDA medium

The essential oils were tested using two methods: the contact or "poisoned food" method (Adam *et al.,* 1998), which involved mixing the essential oils directly into the Potato Dextrose Agar (PDA) culture medium, and the fumigation or micro-atmosphere method, where the essential oils were poured and then spread on the underside of the Petri dish lid (Tonzibo *et al*., 2013). For each type of essential oil, five (05) doses (D) were prepared in the following proportions : D2 (0.1 µl/ml), D4 (0.6 µl/ml), D6 (1.2 µl/ml), D8 (1.8 µl/ml) and D10 (2.4 µl/ml). In both tests, two synthetic fungicides, mancozeb and azoxystrobin, at recommended doses of 6.67 µl/ml and 3.33 µl/ml respectively, and an absolute control were used. Petri dishes were then placed in an incubation chamber. For each method, the thallus diameters (in mm) of colonies in each Petri dish were measured for 14 days after incubation (JAI) at two-day intervals (Sirima *et al.,* 2020 ; Kassankogno, 2016).

- Assessment of mycelial growth : from seven (07) days of pure culture of *M. oryzae*, one (01) explant measuring six (06) mm was removed and placed in the center of the Petri dish containing the culture medium. Mycelial radial growth was assessed by averaging the two (02) perpendicular diameters passing through the middle of the explant (Sirima *et al*., 2020). Three replicates were performed for each concentration.

- Minimum inhibition doses : the inhibition rate (IR) was calculated according to the following formula: $\boldsymbol{TI}_{(\%)} = \left(\frac{T_0 - T}{T_0}\right) \times 100$.. With T0 = mean value recorded in control medium, T = mean value recorded in culture medium containing essential oil or fungicide (Sirima et al., 2020) From these inhibition rates, minimum inhibition doses were determined.

Results

Effects of essential oils on M. oryzae growth on PDA medium

A variation in the radial mycelial growth of *M. oryzae* as a function of the oils and the method used is shown in Figures 1 and 2. Analysis of variance showed a highly significant difference between the radial mycelial diameters of the different essential oils compared with the controls. In the contact method, pure essential oils of *O. americanum, L. multiflora, C. schoenanthus* and *O. gratissimum* inhibited mycelial radial growth of the fungus by 100% at doses D10 (2.4 µl/ml), D4 (0.6 µl/ml), D6 (1.2 µl/ml) and D4 (0.6 µl/ml) respectively. As for the fumigation method, oils of *O. americanum, L. multiflora, C. schoenanthus and O. gratissimum* inhibited 100% of the mycelial radial growth of the fungus respectively from doses greater than or equal to D10 (2.4 µl/ml), D2 (0.3 µl/ml), D6 (1.2 µl/ml) and D8 (1.8 µl/ml). Fungicides based on mancozeb and azoxystrobin inhibited radial mycelial growth by 100% and 25.9% respectively.

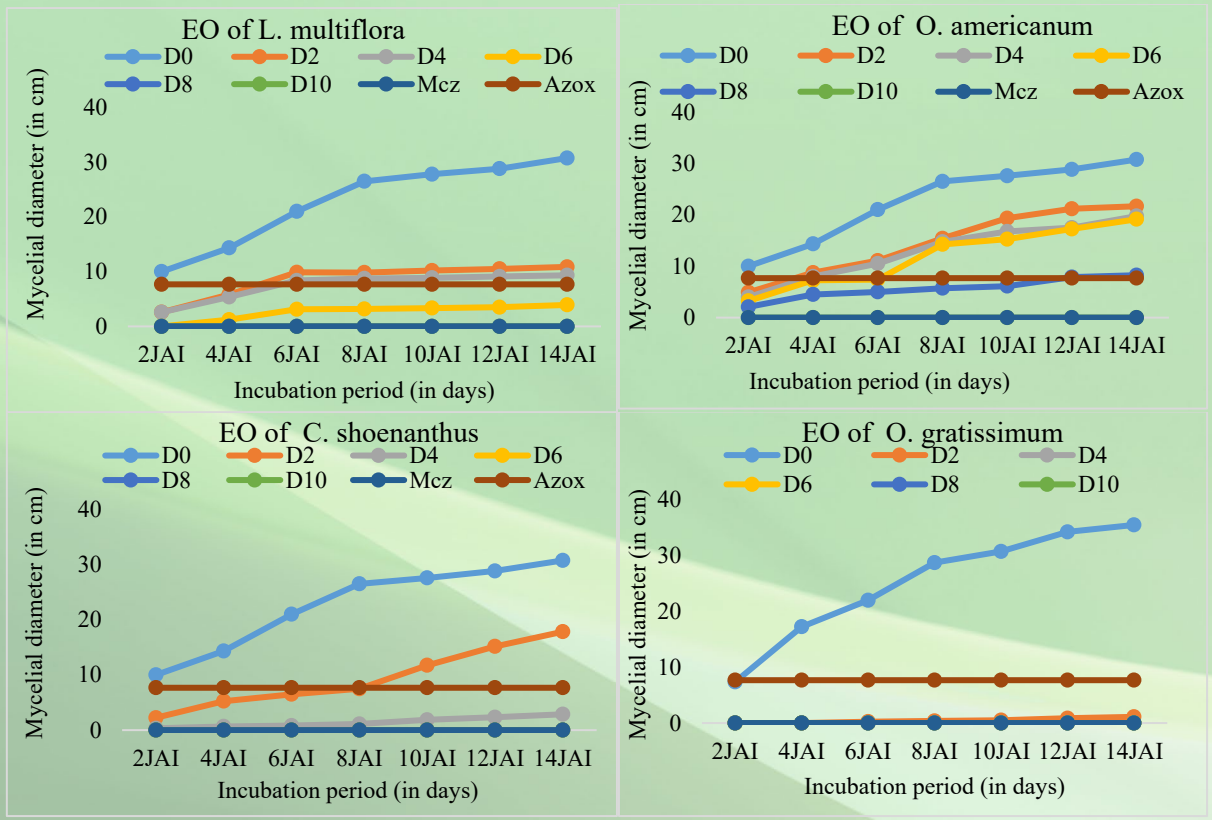


Figure 1 : Evolution of *M. oryzae* mycelial diameter according to incubation time using the contact method.
Legend: JAI = Day after incubation, EO = Essential oil, *Oa = Ocimum americanum, Lm = Lippia multiflora, Cs = Cymbopogon shoenanthus, Og = Ocimum gratissimum.*

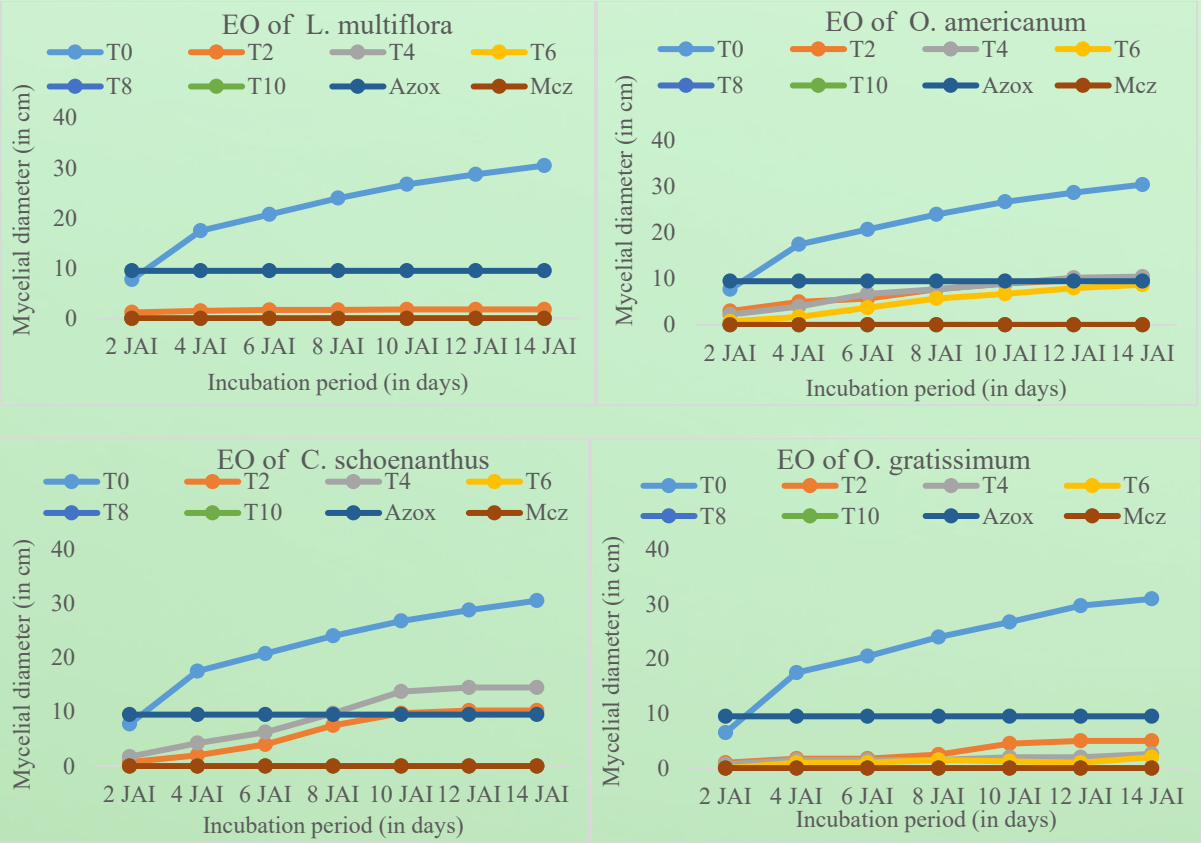


Figure 2 : Evolution of *M. oryzae* mycelial diameter according to incubation time using the fumigation method.
Legend: JAI = Day after incubation, EO = Essential oil, *Oa = Ocimum americanum, Lm = Lippia multiflora, Cs = Cymbopogon shoenanthus, Og = Ocimum gratissimum.*

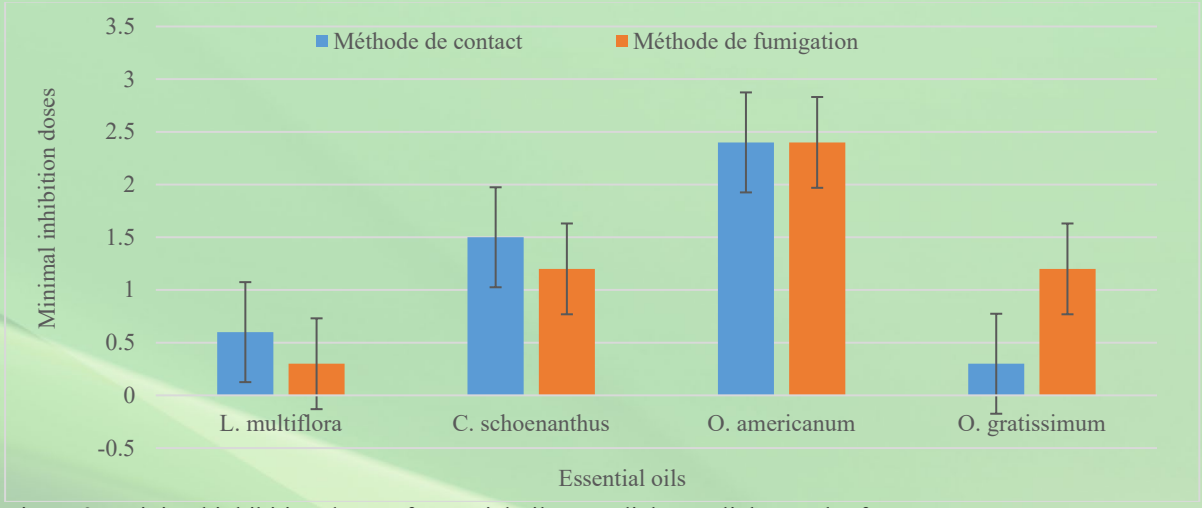


Figure 3 : Minimal inhibition doses of essential oils on radial mycelial growth of *M. oryzae*.

Determination of minimum inhibition doses

The minimum inhibition doses of the various essential oils on radial mycelial growth using the contact and fumigation methods are shown in figure 3.

Analysis of variance showed a highly significant difference between the minimum inhibition doses of the different essential oils. In terms of the parameters evaluated, *O. americanum* essential oil recorded the highest minimum inhibition dose (2.4 µl/ml) in both contact and fumigation methods. In the contact method, *Ocimum gratissimum* oil recorded the lowest minimum inhibition dose (0.3 µl/ml) for all parameters assessed. In the fumigation method, the essential oil of *L. multiflora* applied in pure form recorded the lowest minimum inhibition dose of 0.3 µl/ml on mycelial growth.

Discussion

The effect of essential oils on the growth of *M. oryzae* in vitro varied according to the type of oil and the method used. *O. gratissimum* essential oil was the most effective in inhibiting radial mycelial growth of the fungus. This effectiveness in reducing radial mycelial growth can be explained by its content of major elements, its antifungal properties and its chemical composition, which enable it to stop or slow down the fungus' development (Mohamed *et al.,* 2012). The inhibitory effect of these oils can be attributed to their major compounds, such as 1,8-cineole for *O. americanum* essential oil, or to the synergistic or additive effect of these compounds (Ambindei *et al.,* 2014). According to Sirima *et al.* (2020), the essential oil of *C. schoenanthus* and *L. multiflora* exhibited strong antifungal activity, stopping the mycelial growth of *Alternaria sp* isolates at doses ranging from 5% to 100%.
For Tiendrebeogo *et al*. (2017), the essential oil of *L. multiflora* exhibits strong antifungal activity, totally inhibiting the mycelial growth of *P. oryzae* at 600 ppm. They also showed that this essential oil totally reduced the mycelial growth of F. moniliforme and *B. oryzae* at 100 ppm and 400 ppm respectively. Their work also showed that essential oils were more effective in inhibiting fungal mycelial growth than aqueous plant extracts.
These results can be explained by a probable deactivation or disruption of the fungus's operating system by essential oils. The work of Hamdani *et al* (2015) showed strong 100% inhibition of Fusarium spore germination by *C. aurantium sp* and *F. oxysporum* by *C. sinensis*, while essential oils of *C. limon* and *C. reticulata* stimulated spore germination by 48% and 53% respectively in Alternaria sp. *Magnaporthe oryzae* is a fungus that can infect rice seeds in storage.

Conclusion

The various tests carried out in this study on essential oils and their combinations enabled us to verify their efficacy against *M. oryzae*. All essential oil formulations were effective in inhibiting *M. oryzae*. However, *L. multiflora* oil and *C. schoenanthus* oil used in pure form showed better minimum inhibitory doses on mycelial radial growth of *M. oryzae* spores, with values of 0.6 µl/ml and 1.5 µl/ml respectively. The essential oil of *O. gratissimum* was most effective with a minimum inhibition dose of 0.3 µl/ml. These results attest to the potential of essential oils as a natural means of controlling the pathogen responsible for rice blast. These essential oil formulations can now be tested in real-life conditions to assess their effectiveness in controlling rice blast.

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Author Contributions
OS planned the experiments, interpreted the results, analysed the data statistically, SA and KK supervised the project.

Conflict of interest
The authors declare no conflicts of interest.

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E-Waste Management in the Digital Age: Global Trends, Toxicological Risks, and Green Recovery Technologies

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Abstract
The exponential growth of electronic waste (e-waste) has become an urgent environmental and public health concern due to its toxic composition and propensity for illegal disposal. This review synthesizes e-waste generation, composition, and policy responses globally. It discusses the toxicological risks posed by heavy metals, brominated flame retardants, and persistent organic pollutants contained in the majority of end-of-life electronics. The paper then goes on to discuss emerging green technologies for e-waste recycling such as hydrometallurgical leaching, bioleaching, supercritical fluid extraction, and microfactory systems that minimize environmental damage while maximizing material recovery. It also explores the impact of producer responsibility, integration of the informal sector, and eco-design on the evolution of sustainable e-waste management systems. Global policies, for example, Basel Convention and WEEE Directive, are critically discussed alongside problems of transboundary dumping, informal recycling hazards, and inadequate public enlightenment. The article concludes by propounding multi-stakeholder frameworks towards creating secure, efficient, and equitable circular e-waste systems.
Keywords: E-waste, Toxicity, Recycling technology, Bioleaching, Producer responsibility, Circular electronics

Introduction

New technology diffusion, speedy product development, and push consumption have reduced the product life cycle to unprecedented dimensions, resulting in unprecedented generation of e-waste. Global e-waste generation through 2019 was 53.6 million metric tons, 21% growth over five years, as per Global E-waste Monitor 2020. Global e-waste projection is that global e-waste will surpass 74 million metric tons by the year 2030, an virtual doubling over ten years (Ilankoon et al., 2018).

E-waste, for all its vast resource pool, is otherwise dominated by hazard. Many of the different components are made with lead, mercury, cadmium, brominated flame retardants (BFRs), and persistent organic pollutants (POPs), and both disposal and recycling are complicated and risky unless properly carried out. Compounding the issue is that a mere reported 17.4% of the globe's e-waste has actually been gathered and recycled as such, so the rest has to be treated illegally or informally disposed of (Ahirwar & Tripathi, 2021).

The socio-economic complexity of the e-waste problem is also technical and environmental. The poorly equipped developing world is being used as a dumping site for obsolete electronics in illegal or poorly controlled flows. Workers and local communities in the unorganized recycling that provides livelihood for millions are generally exposed to serious health hazards. The resolution of these issues requires an intervention across the entire range by sets of technological, regulatory, economic, and social measures (Lee et al., 2024).

Toxicological Risks and Environmental Impacts

The toxic chemistry of e-waste results from the chemically diverse composition of metals, plastics, glass, and other additive chemicals. Cadmium and lead are heavy metals that are nephro- and neurotoxic and are extremely toxic to extremely vulnerable groups such as children. Neurological damage and impairment of development have been associated with mercury exposure, which permeates switches and flat-panel displays (Lin et al., 2022).

Brominated flame retardants BFRs or plastic additives used as fire retardants are known endocrine disruptors and possible carcinogens alongside metals. They are also classified as persistent organic pollutants and bioaccumulating substances with a suspected causative role in diseases concerning the thyroid, affected reproduction, and neurotoxicity (Darnerud, 2008).

Environmental contamination caused by e-waste is largely caused by careless recycling. Incinerating wires to obtain copper releases dioxins and furans, the most poisonous chemicals at parts per million. Acidic baths used to recover noble metals off printed circuit boards release heavy metals and sulfuric acid into water and land,

respectively. These contaminants change soil chemistry, lower agricultural yields, and destroy aquatic life (Leung, 2019).

No effect on health deterioration. Recyclers also have very high rates of chronic diseases including respiratory disease, bodywide infection, and skin diseases. In the two biggest e-waste dumping grounds Agbogbloshie (Ghana) and Guiyu (China) compared, their children employed at the dumping grounds have lead blood levels very high, which require immediate intervention (Zeng et al., 2016).

Hence, the toxicological and environmental impact of e-waste in the absence of regulation is not only a local but also a global public health phenomenon demanding attention by coordinated global action and regulatory policies (Li & Achal, 2020).

Innovations in Sustainable Recycling Technologies

The ecological cost of native recycling regimes necessitates more sustainable alternatives. Modern technologies seem promising for eco-friendly disposal of e-waste. Hydrometallurgical operations have recently attracted much attention, involving aqueous solutions for the selective dissolution of metals. These operations are characterized by low temperatures of the processing, lower emissions of processes, and high-purity metal recovery options. The new developments include biodegradable solvents and microbial-derived organic acids that make these operations even more environmentally friendly (Huy Do et al., 2023).

Microbial activity helps in bioleaching and metal recovery during e-waste treatment. Some bacterial types oxidize sulfides of metals and release them in pure form such as gold, copper, and nickel. Compared to traditional processes, bioleaching reactions are long but cost-effective, energy-efficient, and environmentally friendly, especially applied at the industrial scale in optimized bioreactors.

Supercritical fluid extraction (SFE) in supercritical carbon dioxide is solvent-free. SFE has shown a selective disruption of the polymers, flame retardants, and noble metals for clean separations under controlled pressure and temperature conditions (Preetam et al., 2022).

Microfactory concepts are changing the game in decentralized recycling of e-waste management. Modular microfactories with automated processes will convert e-wastes into a diverse range of useable products, including metal alloys, engineered plastics, and glass microfibers. The localization of microfactories minimizes logistic emissions and promotes local economy stimulation through the creation of green jobs. The technical possibilities are therefore very reliant on cooperation between the public and private sectors, favourable governmental policies, and continuity in research and development efforts (Moure Abelenda & Aiouache, 2023).

Policy Frameworks, Challenges, and Opportunities

Policy interventions are the backbone for steering towards sustainable e-waste management, with the Basel Convention being an overarching instrument to regulate transboundary hazardous waste so as to ensure that e-waste is not dumped from developed to developing countries. However, the loophole of the export of "second-hand goods" makes enforcement difficult and continues the cycle of environmental injustice (Aycock et al., 2023).

Extended Producer Responsibility (EPR) under which manufacturers are held liable for the end-of-life management of the products relates to the European Union's WEEE Directive, and has thus led to formal collection schemes, recycling standards, and eco-design practices forming. However, most countries will continue to face such problems such as enforcement of the regulation and industry resistance.

Regulatory frameworks are existing, at best, in only a nascent form or completely ineffective in many low- and middle-income countries. Here, the informal recycling economy has thus far become overwhelmingly predominant. This would therefore demonstrate the possibility of strong initiation of lobbying and development activities for policies that can facilitate this informal sector, such as in training and educational initiatives, certification as well as technology assistance (Ezeudu, 2024).

Reinforcement of these international alliances should be through strengthened capacity building, technology transfers and provision of finances to developing countries to help them develop their infrastructures unsustainably for dealing with e-waste.

In addition to that, policies should look at the upstream intervention of product design in the area of durability, reparability, and recyclability as important design considerations. Without such systemic shifts in the production-consumption aspects, little will be achieved with any regulatory changes (Wene, 2015).

The Role of Consumer Behavior in E-Waste Generation

Consumer behavior thus becomes an elemental factor in affecting the size and composition of the e-waste stream. Rapid turnover due to marketing practices, technological obsolescence, and a social perception of the new technologies as a status symbol is much worsened by the speediness of generation or e-waste (Islam et al., 2021). It further induces a throwaway culture planned obsolescence: products are intentionally designed with limited lifespans. Most consumers may throw away devices that are still functional, simply to acquire the latest models, depleting more resources and compounding an already precarious situation.

Education awareness programs aimed at the consumers on the environmental and health hazards posed by e-waste can also change the landscape significantly. Such estimates can empower consumers to be agents of transformation in the circular economy by encouraging repair, reuse, and even responsible recycling behaviors (Wirtu & Tucho, 2022).

The policy instruments include eco-labeling, right-to-repair laws, and buy-back schemes that encourage sustainable consumer consumption. Companies engage in programs like trade-in old electronics or market their products based on easier repairability; such activities enhance loyalty and appreciation among customers while lessening environment footprints. Ultimately, behavioral dimensioning of et-waste involves consumption culture relocation to maintaining a sustainable culture where stewardship and intergenerational equity become priority concerns (Vidal-Ayuso et al., 2023).

Conclusion

E-waste becomes a product of techno-progress. It improves life, but on the other hand, produces a new element that threatens the ecological and social fabric of the earth. E-waste remains the cause of environmental degradation, toxic exposure, and social inequality in any uncontrolled condition. There which means, the crisis, availing a rare opportunity indeed: green recycling technologies advancing, robust policy frameworks strengthened, informal economies integrated, and consumers' mindsets evolving as a whole may pave the way for new sustainability actions (Bakhiyi et al., 2018).

A circular economy in e-waste requires integrated multi-front action: design of electronics for end of life; sound and enforced policy; financial commitment to innovations in technologies; and change in culture for responsible consumption behavior. The future of e-waste management will not be defined just by the ingenuity of technology but by what really commits our ethical being towards environmental justice, social inclusion, and planetary health for generations to come (Xavier et al., 2019).

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Ecological Logistics Approaches: Supply Chain Strategies for Biodiversity Conservation

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Abstract

The increasing environmental degradation and biodiversity loss caused by industrial activities have prompted the need for more sustainable logistics practices. Ecological logistics, an emerging interdisciplinary approach, focuses on minimizing the ecological footprint of supply chains while contributing actively to biodiversity conservation. This paper scrutinizes how logistics and supply chain strategies could be structured to support ecological balance and the protection of endangered ecosystems. Through sustainable transportation, green warehousing, and ethical sourcing, the study looks into ecological logistics dimensions. This dimension focuses on low-emission transport, optimized routing, and reduced packaging waste as good environmental responsibility examples. It also analyzes how supply chain actors such as NGO's, governments, and local communities can be partners in developing logistics solutions that contribute positively to biodiversity conservation. In examining the cases, the research draws examples from ecological logistics implementation in the forestry, agriculture, and pharmaceutical sectors. These include habitat-sensitive routing journeys, relocation logistics for endangered species, or monitoring biodiversity via supply chain traceability technologies. Further, the authors discuss how digital tools such as GIS, IoT, and blockchain can further support the visibility and accountability required within the supply chain. Findings show that ecological logistics are realizable and vital for initiating long-term sustainable objectives. Designing logistical strategies with biodiversity in mind could be a potential area to gain an upper hand in competition and meet the legal prerequisites of environmental protection and CSR. Ultimately, this paper favors a shift from the purely efficiency-driven models toward eco-centric systems in logistics management, wherein biodiversity is regarded as a significant stakeholder in supply chain design, not an externality.

Key Words: *ecological logistics, biodiversity conservation, sustainable supply chains, green transportation, environmental responsibility*

Introduction

Over the past decades, the unprecedented loss of biodiversity and the relentless degradation of natural ecosystems have become urgent global concerns, significantly shaping the discourse surrounding sustainable development. Conventional logistics models, often driven by cost-efficiency and operational speed, have historically neglected the profound ecological impacts generated throughout the supply chain. The result has been a steady encroachment on natural habitats, increased carbon emissions, and disruptions to delicate ecological balances. In this context, *ecological logistics* emerges not merely as an environmental compliance measure but as a transformative paradigm seeking to harmonize economic objectives with ecological sustainability. This paper aims to dissect how ecological logistics strategies can serve as an effective bridge between efficient supply chain management and biodiversity conservation, offering both environmental and economic benefits for businesses operating in increasingly eco-conscious markets (Smith & Wood, 2018).

Conceptual Framework of Ecological Logistics

Ecological logistics encompasses a strategic approach that reconfigures logistical processes with the explicit goal of minimizing negative environmental impacts, particularly those affecting biodiversity. Unlike broader sustainability efforts that often focus on singular environmental metrics such as carbon reduction or energy efficiency, ecological logistics elevates biodiversity to the status of a critical stakeholder in supply chain decision-making. This paradigm recognizes that logistics activities, ranging from transportation to warehousing and sourcing, directly influence species habitats, ecosystem services, and the integrity of biological networks. Accordingly, ecological logistics involves proactive measures to avoid habitat destruction, mitigate pollution, and ensure the preservation of ecosystem connectivity. It requires integrating environmental data into logistical planning processes, fostering cross-sector collaborations, and adopting holistic performance metrics that capture ecological impacts alongside economic outcomes (*Ecological Framework*, 2010).

Sustainable Transportation Practices

Transportation logistics remains one of the most significant contributors to environmental degradation, primarily through greenhouse gas emissions, particulate pollution, noise, and habitat fragmentation caused by road and rail networks. Ecological logistics calls for transformative approaches in transportation, including: Low-Emission Vehicles: Transitioning fleets to electric, hydrogen-powered, or hybrid vehicles reduces dependency on fossil fuels and lowers carbon footprints. Such transitions, while initially capital-intensive, often result in long-term cost savings due to reduced fuel and maintenance expenses. Habitat-Sensitive Routing: Logistics planners can leverage geographic information systems (GIS) to design transport routes that deliberately avoid ecologically sensitive areas, such as migration corridors, wetlands, and endangered species habitats. This strategy minimizes direct disturbances to ecosystems while also mitigating risks associated with regulatory non-compliance (Tariq, 2024). Load Optimization: By consolidating shipments and increasing load factors, companies can reduce the frequency of trips, thus lowering cumulative emissions and traffic-related environmental disturbances. Adopting sustainable transportation not only mitigates ecological harm but also aligns organizations with emerging regulatory standards and bolsters their reputation among environmentally conscious stakeholders (Jimenez, 2017).

Green Warehousing and Packaging

Warehousing operations contribute significantly to the environmental footprint of supply chains through energy consumption, material waste, and potential impacts on surrounding ecosystems. Ecological logistics emphasizes a multifaceted approach to green warehousing: Energy-Efficient Facilities: Incorporating renewable energy sources, such as solar panels and geothermal systems, alongside high-performance insulation, significantly reduces greenhouse gas emissions. Smart building technologies, including automated lighting and climate control systems, further enhance operational efficiency. Minimized Packaging Waste: Excessive packaging not only increases material costs but also contributes to solid waste challenges (Bergey, 2005). Ecological logistics promotes the use of recyclable, compostable, or biodegradable materials and encourages packaging designs that reduce material usage without compromising product protection. Biodiversity-Friendly Site Design: Warehousing infrastructure can be designed or retrofitted to minimize land disturbance, preserve natural vegetation buffers, and incorporate green spaces that serve as habitats for local wildlife. Green roofs and rainwater harvesting systems contribute to ecosystem health and water management.

Green warehousing practices yield multiple benefits, including cost savings from reduced energy consumption, enhanced brand image, and compliance with increasingly stringent environmental regulations (Castillo, 2022).

Ethical and Responsible Sourcing

Supply chain sourcing activities have profound implications for biodiversity, particularly when raw materials are extracted from ecologically sensitive regions. Ecological logistics mandates responsible sourcing practices that extend beyond traditional supplier relationships:

Supplier Audits: Companies should conduct thorough assessments of suppliers to ensure adherence to biodiversity conservation standards, legal frameworks, and ethical labor practices. Audits help identify environmental risks and promote continuous improvement among partners.

Traceability Systems: Technologies such as blockchain and RFID enable detailed tracking of raw materials throughout the supply chain, offering visibility into sourcing origins and associated environmental impacts. Traceability ensures accountability and helps companies substantiate sustainability claims (Cox, 2025).

Community Collaboration: Engaging local communities as stakeholders fosters mutual benefits, including the preservation of traditional ecological knowledge and the protection of culturally significant ecosystems. Collaborative efforts can facilitate sustainable harvesting practices and the restoration of degraded habitats. Responsible sourcing is not merely an ethical obligation but increasingly a competitive differentiator, as consumers and regulators demand greater transparency and environmental stewardship from businesses (Agrawal & Lee, 2016).

Role of Digital Technologies

Digital transformation plays a pivotal role in enabling ecological logistics. Advanced technological solutions facilitate environmental monitoring, enhance data-driven decision-making, and improve transparency across complex supply chains:

Geographic Information Systems (GIS): GIS technology supports habitat mapping and route optimization, helping logistics planners avoid ecologically sensitive areas. It provides valuable spatial analysis for assessing the potential impact of logistics infrastructure on biodiversity.

Internet of Things (IoT): IoT devices deployed in vehicles, warehouses, and production facilities collect real-time data on emissions, energy usage, and environmental conditions. This continuous monitoring enables proactive environmental management and timely interventions.

Blockchain Platforms: Blockchain ensures secure, tamper-proof recording of transactions and environmental metrics, providing verifiable evidence of sustainable practices. It builds trust with consumers and regulatory bodies, which increasingly demand traceable sustainability credentials.

These digital tools empower logistics professionals to integrate environmental considerations into operational strategies with unprecedented precision, thereby supporting biodiversity conservation goals (Boulehouache et al., 2012).

Sectoral Applications

The principles of ecological logistics are highly adaptable and have found practical applications across diverse industries:

Forestry: Logistics strategies prioritize habitat-sensitive routing for timber transportation to avoid disturbing wildlife corridors. Companies also employ sustainable harvesting schedules that allow forest regeneration and minimize habitat disruption.

Agriculture: Ecological logistics practices involve traceability systems to monitor inputs such as fertilizers and pesticides, which can have cascading effects on local biodiversity. Sustainable supply chains promote organic farming, integrated pest management, and soil conservation measures.

Pharmaceuticals: Many pharmaceutical products rely on biotic raw materials sourced from sensitive ecosystems. Ecological logistics guides ethical sourcing practices that protect endangered plant and animal species while supporting habitat restoration projects.

These sector-specific implementations illustrate how ecological logistics is not a one-size-fits-all solution but rather a flexible framework capable of addressing unique industry challenges while advancing biodiversity conservation (Hines, 2023).

Conclusion

The mounting evidence of ecological crises underscores the urgency of reimagining logistics systems through an ecological lens. This paper has demonstrated that ecological logistics provides a viable and strategic approach to reconcile operational efficiency with the imperative of conserving biodiversity. By embedding ecological principles into transportation, warehousing, sourcing, and digital technologies, businesses can not only mitigate environmental risks but also secure competitive advantages in markets increasingly driven by sustainability expectations. Importantly, ecological logistics reframes biodiversity not as a peripheral concern but as a core stakeholder whose well-being is integral to long-term economic resilience and ethical business practice. Future research should further investigate cross-sector collaborations, policy frameworks, and technological innovations that can accelerate the mainstream adoption of ecological logistics strategies worldwide.

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The Role of Artificial Intelligent in Agricultural Applications: Trend Methods

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Abstract

Artificial Intelligence (AI) is increasingly transforming agriculture by introducing advanced methods that enhance productivity and sustainability. Modern AI applications in agriculture encompass several key areas: *Precision Farming*: AI algorithms analyze data from various sources, including satellite imagery and soil sensors, to optimize planting schedules, irrigation, and fertilization, thereby improving crop yields and resource efficiency. *Crop Monitoring and Disease Detection*: Machine learning models and computer vision techniques enable early detection of plant diseases and pest infestations, allowing for timely interventions and reducing crop losses. *Robotics and Automation*: AI-powered robots are employed for tasks such as planting, harvesting, and weeding, increasing operational efficiency and reducing labor costs. *Supply Chain Optimization*: AI assists in forecasting demand, managing inventory, and optimizing logistics, leading to reduced waste and improved market responsiveness. Despite these advancements, challenges persist, including data quality issues, infrastructure limitations, and the need for regulatory frameworks to ensure safe and ethical AI deployment. Addressing these challenges requires collaborative efforts among policymakers, researchers, and industry stakeholders to develop standards and invest in education and infrastructure. This paper explores the current trends and methodologies of AI applications in agriculture, highlighting their potential to transform the sector and contribute to global food security and environmental sustainability.

Keywords: *Artificial Intelligence, Precision Farming, Machine Learning, Agricultural Robotics, Crop Productivity, Sustainable Agriculture*

Introduction

Agriculture remains a foundational pillar of economic sustainability, contributing significantly to long-term economic growth, employment, and national development. Traditionally focused on food and crop production, the agricultural sector has evolved over the past two decades to encompass processing, marketing, and distribution of both crops and livestock. Today, agriculture not only ensures food security but also supports GDP growth, drives trade, provides raw materials for other industries, and serves as a major source of livelihood across many regions. However, the rapid increase in global population, coupled with challenges such as climate change, land degradation, and labor shortages, demands a fundamental shift in how agriculture is practiced. To meet the growing demand for food in a sustainable and efficient manner, innovative technologies must be integrated into agricultural systems. Among these, Artificial Intelligence (AI) stands out as a transformative tool capable of revolutionizing every stage of the agricultural value chain.

Enabled by advances in big data analytics, robotics, the Internet of Things (IoT), drone technology, and affordable sensors, AI is poised to reshape modern farming. By analyzing data on temperature, soil conditions, weather patterns, moisture levels, and historical crop performance, AI can provide predictive insights—such as optimal planting and harvesting times or the best crop selection for a given region. This not only enhances crop yields but also reduces the reliance on water, fertilizers, and pesticides, thereby supporting environmental sustainability.

Furthermore, AI-driven automation improves labor efficiency and worker safety, optimizes supply chains, and ensures food production keeps pace with population growth—ultimately contributing to lower food prices and improved food security.

This paper explores the current trends, methodologies, and challenges in the application of AI in agriculture. It highlights how AI technologies are enhancing productivity, increasing resource efficiency, and paving the way for a more resilient and sustainable agricultural sector [1].

Precision Agriculture

One of the most prominent applications of AI in agriculture is precision farming. Precision agriculture refers to the use of AI algorithms to analyze data collected from various sources, such as satellite imagery, drones, weather

stations, and soil sensors. These AI systems help farmers make informed decisions about crop rotation, planting schedules, irrigation needs, and fertilizer application. For example, machine learning models can predict soil nutrient deficiencies or moisture levels and suggest targeted interventions, thereby improving crop yield and reducing input costs [2].

Moreover, AI-powered tools can generate customized recommendations for specific plots of land, considering microclimatic conditions and soil properties. This leads to better resource management and helps in reducing water wastage and overuse of agrochemicals. According to Kamilaris et al. (2018), such AI-driven approaches can increase yield by up to 25% while lowering input costs by around 20% [3].

Crop Monitoring and Disease Detection

Another area where AI has shown remarkable potential is crop health monitoring and early disease detection. With the help of computer vision, deep learning, and image recognition techniques, AI can identify early symptoms of plant diseases, nutrient deficiencies, or pest infestations by analyzing leaf patterns, color changes, and growth anomalies.

These technologies allow for real-time monitoring through drones or smartphones equipped with AI-powered cameras. By detecting problems early, farmers can take swift action to prevent the spread of diseases, ultimately minimizing losses and reducing the need for harmful pesticides. An example of such a system is Plantix, a mobile application that uses AI to diagnose plant health issues from photos taken by users in the field [4].

Robotics and Automation

AI is also revolutionizing the physical processes of agriculture through robotics and automation. AI-powered robots and autonomous machinery are increasingly used for repetitive tasks such as planting, harvesting, pruning, spraying, and weeding. These machines are capable of working around the clock and in varying weather conditions, significantly reducing the need for manual labor and improving efficiency.

For instance, robots like the “Agrobot” and “Harvest CROO” can identify ripe fruits and pick them without damaging the crops. Weeding robots powered by computer vision and AI can precisely remove weeds without disturbing the surrounding plants. Such innovations not only enhance productivity but also reduce the exposure of human workers to potentially hazardous conditions.

Forecasting and Supply Chain Optimization

AI also plays a vital role beyond the farm—particularly in agricultural forecasting and supply chain management. Predictive analytics powered by AI can forecast crop yields, monitor market trends, and anticipate consumer demand. This helps in planning storage, transportation, and marketing strategies more efficiently, reducing food waste and ensuring better availability of produce in the market.

Furthermore, AI tools can analyze patterns in supply chains to identify inefficiencies and suggest optimal routing for distribution, thus saving time, fuel, and money. AI systems used in logistics are increasingly capable of dynamic adjustment based on weather patterns, road conditions, or market fluctuations [5].

Sustainable Farming and Climate Resilience

AI contributes significantly to the goal of sustainable farming by enabling smart decision-making that minimizes environmental harm. AI-based systems can suggest eco-friendly pest control, optimal irrigation methods, and sustainable crop combinations that enrich the soil. By enhancing the accuracy of climate forecasts and risk assessments, AI also supports climate-resilient agriculture, helping farmers adapt to changing conditions and natural disasters.

For example, IBM’s Watson Decision Platform for Agriculture integrates AI and IoT to provide farmers with a full spectrum of insights—from planting to harvesting—while emphasizing sustainability and risk reduction [6].

Conclusion

AI technologies are not just reshaping how farming is done — they are fundamentally transforming agriculture into a high-tech industry. From precision farming to disease detection, from robotics to supply chain optimization, AI offers comprehensive solutions that improve efficiency, reduce costs, and promote sustainability. As global agricultural demands continue to grow, the adoption of AI will be critical in creating a more productive and resilient food system.

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Current Strategies in Pest Control Using Biological Agents

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Abstract

Agricultural pests are defined as animals that cause damage and death to crop plants. In recent decades, there has been an increase in the number of pests, including aphids, beetles and locusts, resulting in significant crop losses. Consequently, contemporary agriculture is increasingly reliant on efficacious and secure crop protection products. While various methods of pest control exist, both chemical and biological, it is the former that is more commonly used in practice. These chemical insecticides can exist in a variety of aggregate states (liquid or solid) and are both fast-acting and affordable. However, their significant disadvantage is their ability to accumulate in plants, which can negatively affect the health of consumers.

Consequently, there has been a surge in the development of biological plant protection products, which exhibit a milder and safer action profile. One such agent is a bacterial insecticide based on Bacillus thuringiensis (Bt). This microorganism was first isolated by Berliner in 1915 from dead caterpillars of the miller's fireweed. Subsequent research revealed that the Bt exotoxin (phospholipase C) is responsible for the death of insects, and that its endotoxin, initially non-toxic, is activated in the digestive tract of insects by the action of alkaline proteases and transformed into an active toxin.

Bt insecticides are selective and effective against various pests such as caterpillars, mosquitoes and midges. Due to their targeted activity and environmental safety, Bacillus thuringiensis-based formulations are widely used in biological plant protection. Subsequent reports will address contemporary methodologies for pest management that exhibit high efficiency while causing minimal harm to the environment and human health.

Keywords: Insecticides, Microorganism, Toxins.

Introduction

The widespread increase in agricultural pests in recent decades poses a serious threat to global food supply and sustainable agriculture. Currently, agriculture faces a number of pressing challenges, one of which is to maintain crop yields while ensuring environmental and food security. One of the key factors negatively affecting the productivity of agrocenoses remains pests - insects, mites, nematodes and other organisms that can cause large yield losses and reduce the quality of products. According to the UN Food and Agriculture Organisation (FAO), up to 20-40% of the world's yield is lost annually due to pests, which makes pest control a strategically important task. For many decades, chemical pesticides have been the main method of pest control. Due to their rapid action, wide spectrum of activity and relative ease of application, they have provided stable crop protection under conditions of intensive agriculture.

However, the widespread use of synthetic insecticides has led to a number of serious consequences: establishment of resistant pest populations, destruction of natural ecosystems, death of non-target organisms (including pollinators and natural enemies of pests), contamination of soil and water bodies, and potential threats to human health. These circumstances have necessitated a review of existing approaches to plant protection. With the growing interest in ecologically sound and sustainable agriculture, biological pest control methods are receiving increasing attention. Biological agents are organisms or substances of biological origin that are used to suppress pest populations.

These include bacteria (e.g. Bacillus thuringiensis), entomopathogenic fungi (Beauveria bassiana, Metarhizium anisopliae), viruses (nucleopolyhedroviruses, granuloviruses), parasitoids (trichogramma, horseflies), and predatory insects and mites. The use of such agents provides targeted pest control with minimal impact on the environment and non-target organisms. Biological control can be carried out in various ways: through introduction and acclimatisation of natural enemies, conservation and stimulation of their populations in agrocenoses, as well as the use of biopreparations based on living organisms or their metabolites. Modern biotechnological achievements, including genetic engineering approaches, contribute to the expansion of the arsenal of biological plant protection products and increase their efficiency [1].

The aim of this article is to provide a comprehensive overview of current biological pest management strategies, advantages and limitations. Special attention is given to innovative developments in microbiological preparations, integrated crop protection and the prospects for sustainable agriculture with minimal use of chemicals. The relevance of the topic is due to the need to transition to ecologically balanced farming systems that

meet the challenges of climate change, biodiversity and human health. A comprehensive review of modern biological pest management strategies

Modern approaches to biological pest control represent a multilevel system of measures aimed at reducing the number of pests by means of natural enemies or products of their vital activity.

Biological strategies can be conditionally classified into three main directions: classical (introduction), conservation and applied (or augmentative) biological control. Each of these directions has its own goals, methods of application and area of greatest effectiveness [2].

Classical biological control

The classical strategy consists in the introduction (introduction) of exotic natural enemies of pests into new habitats where the latter lack natural population regulators. It is most effective in controlling invasive pest species. A successful example is the introduction of Encarsia formosa to control whitefly in greenhouse farms. The main advantage of the method is its long-term effect after a single infestation of the enemy, but the effectiveness depends on the degree of adaptation of the biological agent to the new biotope.

Conservation biological control

A conservation strategy aims to preserve and stimulate populations of natural enemies of pests already existing in the agrocenosis. This may include creating favorable habitat for entomophagy, reducing the use of chemical insecticides, ensuring the availability of alternative food sources (e.g. nectar-bearing plants) and conserving landscape diversity. Such measures have proven effective in integrated plant protection systems and contribute to restoring ecological balance in agroecosystems.

Applied (augmentative) biological warfare

The applied strategy consists of mass multiplication of biological agents in laboratory conditions and their subsequent release into the environment. Depending on the objective, inoculative (single release at early stages of infestation) and inundate (mass release at high pest levels) approaches are distinguished. Trichogramma (parasitic webworms) are widely used to control scale pests, as well as entomopathogenic fungi, bacteria and viruses. A significant achievement in recent years is the commercial production of Bacillus thuringiensis (Bt)-based biopreparations with narrow specificity, environmental safety and proven efficacy against a number of insects [3].

Microbiological and viral preparations

Microbiological plant protection agents based on the action of bacteria, fungi and viruses have become increasingly important in the structure of biological protection in recent years. Preparations based on Bacillus thuringiensis are effective in controlling larvae of scales and bivalves. Viral agents such as nucleopolyhedroviruses (NPVs) are used to control caterpillars of pest moths, demonstrating high specificity and safety. The development of preparations based on symbiotic nematodes in combination with bacteria of the genus Xenorhabdus and Photorhabdus is underway, which expands the possibilities of point control of soil pests [6].

Genetic engineering and biotechnology

A significant contribution to biological defence comes from the use of genetically modified organisms. The best known are transgenic plants expressing Bt-toxins that are resistant to a number of pests. Although the use of such crops is a matter of scientific and public debate, they have already proven effective in reducing the use of chemical insecticides, especially in cotton and maize production [3].

Integrated strategies and sustainable agriculture

The most promising approach is Integrated Pest Management (IPM), which combines biological methods with agronomic, breeding and, where necessary, limited use of chemicals. This approach allows achieving high control efficiency while maintaining ecological sustainability and reducing environmental impact. IPM requires systematic monitoring of pest populations, predicting outbreaks and adapting strategies to current conditions.

Advantages and limitations of modern biological pest control strategies

Modern biological pest control methods are considered as an important alternative to chemical pesticides in the transition to sustainable agriculture [4]. However, despite the obvious advantages, biological control is not a universal solution and has its limitations that need to be taken into account when designing and implementing plant protection systems.

*Advantages: E*nvironmental safety. Biological agents are generally highly specific and do not adversely affect non-target organisms, including beneficial insects (pollinators, entomophages), animals and humans. This makes them

attractive in programs to protect biodiversity and reduce anthropogenic pressure on ecosystems. The lack of resistance in pests (if applied correctly) is also an important factor.

Unlike chemical insecticides, to which pests quickly develop resistance, biological agents - especially in integrated strategies - create more complex selection pressures that reduce the likelihood of resistance [5]. Compatibility with organic farming.

Biological products and methods based on the use of living organisms are authorized in most organic certification systems (e.g. EU, USDA Organic), making them indispensable in organic agro-technologies. Selectivity of action.

Most biological agents affect only certain groups of pests, thus preserving beneficial fauna and natural population regulators in agrocenoses. Reduction of residues in products. Biological preparations do not accumulate in plants and the environment, which improves the quality and safety of agricultural products, reduces health risks for consumers and facilitates export to countries with strict phytosanitary requirements.

Limitations: Slow and condition-dependent action.

Unlike chemical insecticides, biological agents often act more slowly, especially under unfavorable weather conditions (high temperature, drought, UV radiation), which can be critical when pest populations increase dramatically. High specificity.

While specificity is an advantage, it also limits the use of a single product against different pest species. This requires accurate diagnosis of the problem and often more complex logistics in application. Storage and transport difficulties.

Many biologics (especially live crops) are sensitive to storage conditions (temperature, humidity), which limits their shelf life and requires strict adherence to transport conditions. The need for an integrated approach and monitoring.

To achieve high efficiency of biological control, a systematic approach is required: monitoring pest numbers, forecasting outbreaks, understanding the biology of the enemy and the agent. This requires qualified personnel and scientific support [7]. Limited number of registered drugs.

In some countries and regions, the market for biological defense products is underdeveloped. There are fewer registered effective and available preparations than chemical analogues, which restrains the widespread adoption of bio methods. Development and implementation costs.

The development and commercialization of new biological agents requires significant investment in research, laboratory production and field trials, which can stifle innovation in this area [8]. Despite some limitations, biological pest management represents an important part of a sustainable and ecologically oriented agricultural system. Given the global challenges - climate change, soil degradation, increasing pest resistance to chemicals - biological strategies are becoming increasingly important. The introduction of integrated plant protection systems combining biological, agronomic and, if necessary, chemical measures is the most rational way to a sustainable and environmentally friendly agriculture of the future [9].

Innovative development of microbiological preparations in the system of integrated plant protection as a basis for sustainable farming with minimal use of chemical agents

Sustainable farming in modern conditions requires transition from intensive use of chemical means of plant protection to more environmentally friendly and safe technologies. One of the key directions of such transition is the development and introduction of microbiological preparations in the system of integrated plant protection. These preparations are based on the use of natural microorganisms - bacteria, fungi, actinomycetes and viruses, which have the ability to suppress phytopathogens, stimulate plant growth, improve soil structure and enhance crop immunity [10]. Innovative new-generation biopreparations are developed taking into account specific agroecological conditions, biological compatibility with crops and effectiveness against certain pests. The most widely used strains are Bacillus subtilis, Pseudomonas fluorescens, Trichoderma harzianum, Metarhizium anisopliae and others.

Thanks to the development of biotechnology, forms of preparations with prolonged action, resistance to temperature fluctuations and UV radiation are created, which increases their practical value. Integration of such preparations into the plant protection system makes it possible to significantly reduce or completely replace chemical fungicides, insecticides and nematicides. This, in turn, reduces environmental pollution, preserves useful soil microflora, improves the quality of agricultural products and contributes to the restoration of the natural balance. The use of microbiological means and requires a systematic approach: monitoring of pathogens, selection of optimal time of treatment, crop rotation and combination with other methods of protection. Thus, innovative microbiological developments are becoming an integral part of biologisation of agriculture and the basis for sustainable, environmentally oriented agricultural production [11].

Conclusion

Modern strategies of plant pest protection are increasingly oriented towards environmentally safe and sustainable approaches, among which biological control occupies a special place. In contrast to the traditional use of chemical insecticides, biological methods are based on the use of living organisms - entomophages, pathogenic microorganisms (viruses, bacteria, fungi), as well as natural regulators - pheromones and plant extracts. Biological means not only provide effective suppression of pests, but also contribute to the preservation of ecological balance in the agro-ecosystem.

One of the key advantages of these methods is the lack of resistance in pests when properly applied, making biological defence a sustainable tool in the long term. Modern biosecurity strategies involve the integration of different approaches: release and conservation of populations of beneficial insects, use of microbiological preparations (based on Bacillus thuringiensis, Metarhizium anisopliae, Beauveria bassiana, etc.), use of pheromone traps and attractants for pest monitoring and management. The development of technologies for mass production of entomophages and biopreparations, as well as precise planning of their application using modern digital platforms, also plays an important role. With global climate change and increasing pest resistance to chemistry, biologicals are becoming an integral part of integrated crop protection strategies. Their use in combination with agronomic measures and modern monitoring systems opens the way to sustainable and environmentally friendly agriculture of the future.

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Bee venom: A Natural Agent in the Treatment of Human Diseases

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Abstract

Bee venom is a complex biological active product that is produced by the venom glands of honeybees. Its utilisation in the folk medicine of diverse cultures, including those of India, China and Greece, dates back millennia. In the contemporary medical context, the therapeutic potential of bee venom has garnered significant attention, with numerous studies supporting its role as a natural remedy for a wide range of diseases. The chemical composition of bee venom is intricate, comprising over 40 active components, the most significant of which are melitin, apamin, adolapin, hyaluronidase and phospholipase A2. These substances have been shown to possess anti-inflammatory, analgesic and antibacterial properties. Melitin in particular has garnered significant attention due to its remarkable anti-inflammatory properties, thus positioning it as a potential therapeutic agent for conditions such as rheumatoid arthritis, osteoarthritis, and sciatica, among others that affect the musculoskeletal system. In addition, studies demonstrate the potential of bee venom in treating nervous system disorders such as multiple sclerosis, Parkinson's disease and neuropathies. Apitherapy, a therapeutic modality that involves the utilisation of bee-derived products, encompasses both direct bee stings and the application of ointments, creams, and injections containing purified apitoxin. The study of the antitumour properties of bee venom is of particular interest. In vitro studies have demonstrated that melittin, a component of bee venom, can trigger apoptosis (programmed cell death) in cancer cells without significant harm to healthy tissues, suggesting its potential for use in the development of novel anti-cancer therapies. However, it is imperative to exercise caution when utilising this therapy, as it can potentially induce severe allergic reactions, including anaphylactic shock. Consequently, prior to the initiation of any therapeutic intervention, it is imperative to seek the counsel of a medical professional and undergo allergy assessments. The potential of bee venom as a valuable natural resource with a wide range of therapeutic effects is therefore evident. Further study of this substance and its integration into mainstream medicine may lead to new treatments for a range of chronic and intractable diseases.

***Keywords*:** bee venom, chemical composition, disease, treatment

Introduction

Apitoxin, a complex biologically active substance produced by the glands of bees, has been utilized for centuries in folk medicine for the treatment of various human diseases. In recent decades, there has been a notable increase in the scientific interest in bee venom, owing to the substance's diverse pharmacological effects and its potential for the treatment of human diseases. As stated by Smith et al. (2022), bee venom is comprised of a multitude of biologically active substances, including but not limited to melittin, apamin, phospholipase A2, hyaluronidase, and various amino acids. The unique properties of these substances have the capacity to affect the cells and tissues of the body. Recent medical research and clinical trials have demonstrated the efficacy of bee venom in the treatment of inflammatory diseases, including osteoarthritis and rheumatoid arthritis, as well as neurodegenerative disorders, such as Parkinson's disease. Osteoarthritis is a degenerative joint disease, characterized by the destruction of cartilage and alterations in joint structure. The principal symptoms encompass discomfort, impaired mobility and inflammation. In contradistinction to rheumatoid arthritis, osteoarthritis is not associated with systemic inflammation or immune system disorders. Rheumatoid arthritis is an autoimmune disease in which the immune system mistakenly identifies joint tissues as foreign agents and attacks them, causing chronic inflammation. This can result in joint damage and even joint deformity. In addition to the manifestation of joint problems, rheumatoid arthritis has the potential to affect other organs. Moreover, the therapeutic potential of bee venom extends to the fields of cosmetology and dermatology. The anti-inflammatory and antimicrobial properties of bee venom have been demonstrated to be efficacious in the treatment of acne, psoriasis and other dermatological conditions (Smith et al., 2022). Furthermore, the potential of bee venom in oncology is equally promising, with its components demonstrating the capacity to induce apoptosis in tumour cells. However, despite the promising results, the use of bee venom is associated with a number of risks, including the possibility of allergic reactions. In order to avoid such risks, strict monitoring and dosing is required when using it for therapeutic purposes. In this context, further research is required to improve methods for the safe use of bee venom, as well as to better understand its molecular mechanisms of action. The objective of this paper is to evaluate the extant data on the medical use of bee venom, to identify its therapeutic potential and limiting factors, and to discuss the prospects for its further use in clinical practice [1].

Present status of research on the utilization of bee venom

The utilization of bee venom, otherwise referred to as apitoxin, has a long history in folk and traditional medicine. However, it is only in recent decades that scientific research has begun to comprehensively study its therapeutic properties. Recent studies have corroborated the high biological activity of the components of bee venom, with particular emphasis on melittin, which has been shown to possess significant anti-inflammatory, antimicrobial and antitumor properties [2]. In light of recent advancements in biotechnology and pharmacology, the potential of bee venom as a therapeutic agent for the management of oncological, autoimmune and neurological diseases has been a subject of considerable interest. The necessity for new, safer and more effective therapeutic approaches, as well as the growing interest of the scientific community in natural compounds in medicine, renders the topic highly relevant. The utilization of bee venom in therapeutic contexts can be categorized into several primary directions. Its use in oncology is of particular pertinence. In recent years, melittin has attracted the greatest attention from researchers. This is because it is considered to be the main component of bee venom. As demonstrated in, it has exhibited the most significant activity against a variety of malignant tumors, including those affecting the breast, liver, lung and skin [3]. Melittin has been shown to have the capacity to disrupt tumor cell membranes, thereby inhibiting their growth and inducing apoptosis, or programmed cell death. Furthermore, it has been demonstrated that this compound can enhance the effects of chemotherapy drugs such as doxetaxel while concomitantly reducing their toxic effects on healthy vital tissues. The subsequent focus will be on the treatment of inflammatory and autoimmune diseases. The utilization of bee venom in the therapeutic management of rheumatoid arthritis, osteoarthritis, and other inflammatory joint diseases has gained significant traction in recent years. A substantial body of research has repeatedly demonstrated that regular injections of low doses of apitxin have a significant analgesic effect, reduce inflammation, and enhance joint mobility. Research is also ongoing into the use of bee venom in multiple sclerosis, where it shows potential as a neuroprotective and immunomodulatory agent. Another popular application of the technology is in the fields of neurology and dermatology. Its utilization is prevalent in the treatment of diseases affecting both the central and peripheral nervous systems, encompassing conditions such as neuralgia, radiculitis, and paralysis. It is evident that apamin exerts a stimulant effect on the nervous system, albeit one that is mild in nature. In the field of dermatology, research is underway to explore the potential of bee venom as an active ingredient in cosmetic products, with a view to treating conditions such as psoriasis, acne, and promoting skin rejuvenation. In contemporary times, the administration of bee venom can be accomplished through a variety of methodologies. These include the utilization of direct bee stings, the injection of purified venom, the application of ointments and creams, and the formulation of nano preparations and transdermal patches. Contemporary pharmacological formulations enable more precise dosage regulation and mitigate adverse effects. This is widely regarded as one of the most significant advantages of the method of application. However, despite the promising results of this study, the use of bee venom requires caution and should be carried out strictly under the supervision of specialists, taking into account possible allergic reactions and individual intolerance. In the future, the expansion of the potential applications of apitoxin in modern medicine will be driven by in-depth clinical studies and the development of safe pharmacological forms [4].

Thirdly, the therapeutic potential of bee venom will be examined in detail.

The apitoxin is produced by a special gland in the abdomen. The venom itself is transparent and has a bitter taste. It is noteworthy that the odor rarely resembles the smell of ripe bananas. It is highly soluble in water and acids, but almost insoluble in alcohol. The venom contains approximately 30% solids, and its drying process occurs rapidly at ambient temperatures. The resultant solid is of a viscous nature. It is evident that bee venom is a distinctive pharmaceutical agent that has been utilized since the inception of beekeeping. The treatment of bee venom is a distinctive and time-honored technique. It has become one of the most valuable healing methods, having withstood the test of time. The effectiveness of bee venom is measured in units of 0.1 mg, which is equivalent to the amount of venom typically found in a bee sting. Excessive ingestion of bee venom has been demonstrated to induce anaphylactic shock, with the potential for fatal consequences. The pharmaceutical substance is administered in minimal doses for therapeutic purposes. The efficacy of bee venom is attributable to its ability to stimulate the body's innate capacity to counteract the disease with immediate effect. It has been demonstrated that the application of bee venom results in an increase in blood flow at the site of the sting. The process of destruction of microbes and already damaged tissues is initiated by antibodies, defense cells and enzymes. Inflammation caused by the venom is known to dissipate rapidly, with foreign elements and altered chemicals being eliminated from the affected area. It is evident that bee venom exerts a marked influence on the immune, vascular and nervous systems [5]. The following investigation will explore the mechanisms by which bee venom exerts its effects. The efficacy of bee venom is attributable to its ability to stimulate the body's innate capacity for immediate disease resistance. It has been demonstrated that the application of bee venom results in an increase in blood flow at the site of injection. The process of destruction of microbes and already damaged tissues is initiated by antibodies, defense cells and enzymes. The inflammation caused by the venom is known to dissipate rapidly, accompanied by the removal of foreign bodies and altered chemicals from the affected area. The range of applications of bee venom is extensive. It is evident that bee venom exerts a marked influence on the immune,

vascular and nervous systems. Furthermore, it has been demonstrated that the activation of this process results in the production of hormones that are essential for the suppression of pathologies. Furthermore, the venom activates the work of all systems and organs. The bee bath has been employed in the treatment of a wide range of ailments, including diseases of the nervous system (e.g. neuralgia, radiculitis, plexopathy, neuritis), the muscular system, polyarthritis, traumatic lesions, thrombophlebitis, hypertensive diseases, pneumonia, asthma, prostatic diseases, psoriasis, gynecological diseases, trophic ulcers, and eye diseases [6]. Indications for treatment with bee venom. The utilization of bee venom as a component of a multifaceted therapeutic approach is indicated for the management of chronic infectious diseases, which frequently emerge as a consequence of multifarious exacerbations precipitated by immune system deficiencies. It is an effective pharmaceutical agent employed in the treatment of rheumatic diseases for which hormonal therapy is the standard of care. In this particular instance, bee venom constitutes a highly effective alternative, given that, in contrast to hormones, this substance is not associated with the development of dependency. The utilization of bee venom has been demonstrated to be efficacious in the treatment of metabolic disorders of various etiologies. In this case, the stimulation is systemic. Following the conclusion of the treatment sessions, a number of changes to the body are observed. Firstly, the metabolism of lipids is restored to normal levels. Secondly, memory is improved. Thirdly, the blood pressure is normalized. Finally, the salts that are deposited in the spinal and joint regions are dissolved. The utilization of bee venom in the treatment of chronic hepatitis and cirrhosis of the liver has also been documented. The therapeutic benefits of bee stings extend to the treatment of scars, the alleviation of sciatic pain, and the management of sciatic attacks. It is asserted that a multitude of diseases can be remedied through a single session of bee stings. Prior to the administration of venom, it is imperative to seek the counsel of a medical professional. It is imperative to recall that the lethal dose of bee venom is 0.2 g, which is equivalent to 300–500 stings. The effectiveness of this method is contingent upon the subject's weight. However, it should be noted that some individuals are allergic to bee venom, and death can result from a single sting. The therapeutic modality that utilizes bee products, including bee venom (apitoxin), is now designated as apitherapy [7]. This approach is currently employed in both conventional medicine and folk practice, due to the aforementioned properties of the substance. A taxonomy of apitherapy methods has been established. Bee stinging is a conventional technique in which bees inject their venom into specific body parts. The procedure is carried out under the strict control of a specialist to avoid allergic reactions. The application of ointments and creams is an essential component of a comprehensive healthcare regimen. The utilization of ointments and creams containing bee venom facilitates the administration of the therapy in the comfort of one's own home. Examples of such means include "Apizartron," "Virapin," and "Sofya" [8]. These substances have been demonstrated to be efficacious in the treatment of joint diseases, inflammation, and back pain. Injections and ampoule preparations. The utilization of bee venom, administered via a syringe, enables precise dosing of the substance and targeted delivery to specific anatomical regions. This method is employed in the treatment of chronic inflammation and pain. The injection of bee venom into the body is achieved through the utilization of either an electric current or ultrasound, thereby facilitating the application of electrophoresis and phonophoresis, respectively. The efficacy of these remedies extends to conditions such as osteochondrosis, sciatica, and arthritis. Apimassage, a therapeutic modality involving the application of creams containing bee venom, has been demonstrated to promote enhanced blood circulation and muscular relaxation through massage. This method is employed in the treatment of diseases of the musculoskeletal system [9].

It is imperative to exercise caution in the following instance:

Allergic Reactions: Individuals with a history of allergic reactions to bee venom should exercise caution and avoid apitherapy whenever possible, as there is a risk of severe reactions, including anaphylaxis.

A consultation with a physician is necessary. It is imperative for individuals to consult with a physician prior to the initiation of treatment, particularly in cases of chronic conditions or allergies.

Professional supervision: It is imperative that all treatments be administered by a duly qualified professional, thereby ensuring the minimization of potential risks and the maximization of treatment efficacy [7].

The Physical and Chemical Properties of Bee Venom

Bee venom is a complex mixture of more than 50 active components, including:

Proteins and peptides constitute approximately 88% of the dry matter. Melittin, the principal toxic component, exhibits anti-inflammatory and anti-tumor effects. Its concentration ranges from 40 to 50.

Apamin, a neurotoxin, has been shown to block potassium channels.

Phospholipase A2 has been demonstrated to disrupt cell membranes and increase inflammation.

Hyaluronidase, an enzyme that increases tissue permeability, is another potential factor to consider.

Amines;

Histamine, dopamine, and norepinephrine (which play a role in inflammation and pain)

The minerals in question include magnesium (Mg), calcium (Ca), phosphorus (P), and trace elements [10]. The physical properties are summarized in Table 1.

Table 1 - Physical properties and its characterization

Property	Characterization
Shape	When fresh, it is a clear, slightly viscous liquid with a pungent odor; when dried, it is a white or yellowish powder
Color	Transparent or light yellow
Smell	Sharp, irritating, similar to acetic or ammonia
Taste	Bitter and burning
Solubility	It is well soluble in water, poorly in alcohols and fats.
pH	Acidic environment, pH ≈ 4.5 - 5.5
Melting point	There is no exact value, but when heated above 60 ° C, the destruction of proteins begins.
Stability	It quickly loses activity in light, when heated, and when in contact with air.

Conclusion

The utilization of bee venom for medicinal purposes constitutes an ancient practice that is increasingly substantiated by contemporary scientific research. For centuries, the therapeutic use of bee venom in folk medicine has been documented for a wide range of ailments, including arthritis, neurological disorders, skin diseases, and even cardiovascular pathologies. In recent decades, scientific research has confirmed the effectiveness of apitherapy in treating a number of diseases. For instance, the therapeutic application of bee venom has been demonstrated in the treatment of osteochondrosis, sciatica, osteoarthritis, and joint diseases. The therapeutic benefits of bee venom include its capacity to reduce inflammation and pain, enhance blood circulation, and restore mobility. However, the utilization of bee venom is not without contraindications. Apitherapy is a therapeutic modality that has been demonstrated to elicit allergic reactions, including anaphylactic shock. Prudent care is therefore paramount when undertaking this practice. Consequently, individuals contemplating the use of bee venom should seek medical counsel and undergo allergy assessments. It is imperative to meticulously observe the dosage and take into account the unique characteristics of the patient. Therefore, it can be concluded that bee venom has the potential to serve as a therapeutic remedy; however, its utilization must be meticulously regulated. A meticulous examination of the advantages and disadvantages reveals that apitherapy has the potential to enhance conventional therapeutic modalities. However, it is imperative to exercise caution and seek the expertise of a qualified professional to ensure its optimal implementation.

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Next-Generation Bioelectrochemical Systems: Bridging Synthetic Biology and Green Electronics to Harvest Renewable Energy

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Abstract

With a rise in the world's energy demand and fossil fuel dependency, there has been an urgent need for sustainable and renewable power systems. In this mini-review, recent developments in bioelectrochemical systems (BESs), i.e., microbial fuel cells (MFCs), enzymatic bio-batteries, and photobioelectrochemical platforms integrating synthetic biology and nanotechnology for power generation are discussed. These systems exploit the electrochemical potential of microbial metabolism and enzymatic redox reactions to generate electricity from organic substrates, wastewater, and sunlight. The review is focused on genetic engineering of electroactive microbes, designer enzymes for optimal electron transfer, and nanostructured electrodes for improved efficiency and scalability. It also briefly discusses real-world applications including biosensing, remote power generation, and wastewater treatment with simultaneous energy recovery. The capacity to utilize them as components of decentralized low-carbon energy systems makes them a viable solution to both energy access and environmental sustainability in the climate crisis context.

Keywords: *Bioelectrochemical systems, Microbial fuel cells, Synthetic biology, Renewable energy, Enzymatic bio-batteries, Green electronics*

Introduction

With the rising global energy demands and the associated environmental consequences of fossil fuel burning, green and sustainable renewable green technologies have evolved. While conventionally existing fossil energy sources are still major greenhouses and carbon change emitters, a push towards the setting up of alternative mechanisms technology-friendly as well as greener is the global agenda today. Among the emerging options under investigation, bioelectrochemical systems (BESs) have garnered considerable attention due to their ability to produce electricity directly from organic substrates via biological means (Bajracharya et al., 2016).

Bioelectrochemical systems are a suite of technologies including microbial fuel cells (MFCs), enzymatic bio-batteries, and photobioelectrochemical platforms. Bioelectrochemical systems take advantage of the redox properties of enzymes and microbes to generate electric power from waste-based or renewable feedstocks like wastewater and light. Efficiency and scalability of BESs have greatly enhanced with the development of nanotechnology and synthetic biology, and hence are playing a crucial role in real-life applications (Hamelers et al., 2009).

This review attempts to locate the newest developments within the field of BESs, highlighting synergy between synthetic biology and green electronics towards optimizing the efficiency of energy conversion. It also refers to practical applications and how BESs will be in a position to provide support to decentralized, low-carbon energy systems and especially solving the global climate issue. The increasing global energy demand and the environmental impacts of fossil fuels have seen the creation of green and environment-friendly renewable energy technologies. Whereas fossil energy reserves continue to represent major drivers of greenhouse gases emissions and global change, exploring alternatives that are environmentally friendly, technologically-based is now the concern of international significance. Of these new options sought, BESs have generated considerable attention in that they are capable of deriving electricity from organic substrates by biological conversions directly (Fang et al., 2020).

Recent Developments in Bioelectrochemical Systems

There has been spectacular development in bioelectrochemical systems (BESs) over the past few years, with electrochemical and biological developments of interest. Microbial fuel cells (MFCs) are one of the many configurations, which have emerged as a model system of choice. MFCs use electroactive bacteria to oxidize organic substrates, with electrons transferred to an anode and electricity as a byproduct. Enhancements in metabolic engineering and microbial strain choice have accelerated electron transfer rates to yield greater energy and system stability (Schaetzle et al., 2008).

Another area of high promise is enzymatic bio-batteries, which make use of the purified redox enzymes to catalyze directly on the surface of the electrode. These systems offer biochemical pathway control and are well suited for application for utilization in miniaturized power systems for biomedical and remote-sensing applications. Enzyme stability and efficient electron transfer remain the major challenges (Buaki-Sogó et al., 2020).

Photobioelectrochemical systems are a cross-platform system that consists of photosynthetic microorganisms or light-sensitive enzymes in combination with electrochemical interfaces for the harvesting of solar energy. The platforms are gaining popularity due to their dual function of light energy conversion and bioremediation.

In addition to these, the use of novel materials such as carbon nanostructures, metal-organic frameworks (MOFs), and conductive polymers has also improved electrode conductivity and biocompatibility. All of these individually and collectively have resulted in enhancements in better performance measures such as power density, Coulombic efficiency, and operating life, which enable wider application of BESs to practical applications (Majumdar et al., 2017).

Integration of Synthetic Biology and Nanotechnology

The combination of synthetic biology and nanotechnology has revolutionized the designing of future bioelectrochemical systems (BESs) with the potential to regulate biological and electrochemical processes more precisely. Synthetic biology offers efficient ways of re-designing microorganisms to realize better electron transfer, metabolic yields, and substrate utilization. Genetic engineering of electroactive bacteria such as Shewanella oneidensis and Geobacter sulfurreducens has provided strains overexpressing cytochrome, conductive pili, and biofilm forming ability, all of which have been helpful in enabling electron transfer to the electrodes (Chen et al., 2022).

In the meantime, optimization of BES component structure and function is within the realm of nanotechnology. Nanostructured electrodes including carbon nanotubes, graphene, and nanofibers exhibit high surface area, improved conductivity, and improved microbial adhesion. All these attributes improve efficient electron transfer as well as reduce internal resistance for further improvement in overall system performance. In addition, immobilization of redox enzymes on nanomaterials has improved enzyme stability and efficiency of catalysis in enzymatic bio-batteries (Kim et al., 2024).

The merging of these two disciplines also enables the development of hybrid bioelectronic interfaces in which the biological systems are interfaced with electronic devices. These structures should extend the limits of scaled, miniaturized, and high-performance devices that can find applications in wearable biosensors, autonomous environmental sensing networks, etc.

By leveraging novel nanotechnology and synthetic biology techniques, BESs are being designed to function more effectively, for longer, and multi-dimensionally for a variety of energy and environmental applications, a step towards decentralized and sustainable energy generation (J. Kim et al., 2018).

Applications in Renewable Energy and Environmental Sustainability

Bioelectrochemical systems (BESs) possess tremendous potential for solving the most important problems of renewable energy generation and environmental protection. With their unique feature of generating electricity from organic wastes, wastewater, and solar power, BESs become twin-function technologies with the potential of clean energy as well as environmental sustainability (Wilberforce et al., 2020).

One of the most significant applications of BESs is wastewater treatment and power generation. In microbial fuel cells (MFCs), wastewater organic pollutants are oxidized by electroactive microbes and result in simultaneous pollutant abatement and electricity production. This not only reduces the environmental cost of wastewater discharge, but it also offsets the energy need of traditional treatment plants.

BESs are further explored for application in biosensing, where growth of microbes or electrochemical response is employed as a marker to indicate the existence of toxins, pathogens, or specific chemicals. These systems find great application for remote or real-time monitoring for environmental and biomedical applications (Daniel et al., 2009).

In decentralized power supply and off-grid, photobioelectrochemical cells and enzymatic bio-batteries can power small electronic devices in remote or poor regions. Biodegradable and low impact on the environment render them to be used for low-impact or short-term applications such as disaster relief regions, wearables, and IoT (Mukha et al., 2020).

Besides other uses, BESs also offer carbon-free energy grids, compatible with renewable energy grids. BESs are capable of offering circular energy systems with biomass and solar supply, especially for rural or developing regions lacking conventional energy infrastructure. In these diversified applications, BESs demonstrate green electronics and sustainable design principles and offer a way to integrated solutions to energy shortages and ecosystem degradation (Zhang et al., 2019).

Conclusion

Bioelectrochemical systems (BESs) are a new field of investigating sustainable, decentralized energy sources. By tapping into the intrinsic redox potential of microbes and enzymes, and further enhancing their performance with the aid of synthetic biology and nanotechnology, the systems can be utilized to convert solar energy and organic wastes into edible electricity. This renders BESs not only clean energy generators but also environmental remediation and biosensing multidisciplinary platforms.

Despite recent advances, several issues need to be addressed before large-scale applications. These involve improving the long-term stability of enzyme and biological components, electron transfer efficiency, reducing system cost, and increasing production scale without losing performance. Regulation and public perception concerns may also influence commercialization rates.

Future studies will have to tackle the development of genetically designed microbial consortia, novel bio-nano interfaces, and smart control systems that allow BESs to respond dynamically to environmental changes. Integration with other renewable technology, i.e., solar or wind technology, could also facilitate hybrid platforms of peak energy yield and reliability.

In brief, as the global energy portrait transitions towards sustainability, bioelectrochemical systems are a promising, sustainable alternative. Interdisciplinary research will continue to be crucial in unlocking their complete potential and making them economically feasible components of green energy infrastructure in the future.

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Traceability in Food Logistics: From Farm to Fork

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Abstract

Traceability is an important cog in the machinery of modern food logistics systems for attaining the twin objectives of transparency, safety, and efficiency along the food supply chain. Traceability systems allow for real-time monitoring, verification, and response by stakeholders in food production and consumption, from farm to fork, to any issues concerning quality or safety. Thus, this study proposes investigating the traceability of food logistics and the ensuing role in food safety, compliance, and consumer trust. The main focus of the paper is on the structure and operation of traceability systems, resulting-from-technologies like barcoding, RFID, IoT devices, and blockchain applications. These technologies promote the tracing of food products through supply chain nodes: producers, processors, distributors, and retailers: while enabling faster corrective action. The analysis of the cases three from developed countries and three from emerging ones reveals best practices and widespread challenges in the adoption of traceability systems. The study also points to the increasing relevance of end-to-end visibility for sustainable and resilient food supply chains. With growing global trade in food and consumer awareness, traceability is no longer a regulatory requirement but also a strategic marketing tool to gain a competitive edge. Hence, the research elaborates that proper traceability improves accountability, risk management, and trust among stakeholders in food logistics operations. The study recommends investments in traceability technologies and alignment with regulations as critical for making food logistics systems evolve in today's increasingly complex global environment.

Key Words: *traceability, food logistics, supply chain, food safety, transparency, farm to fork*

Introduction

The globalization of food markets and the intricate nature of contemporary supply chains have introduced significant challenges to ensuring food safety, quality, and authenticity. Past incidents involving contamination outbreaks, mislabeling, and fraudulent practices have diminished consumer confidence and have highlighted the need for robust transparency throughout food logistics systems. Within this evolving landscape, traceability has emerged as a critical instrument, transcending mere regulatory compliance to become a strategic asset for enhancing brand reputation, managing risks, and fostering consumer trust. This paper delves into the notion of traceability in food logistics, examining its technological foundations, operational processes, and strategic importance in guaranteeing a secure and sustainable food supply chain from farm to fork (Singh et al., 2017).

Conceptualizing Traceability

Traceability in the context of food logistics signifies the systematic ability to monitor and document the journey of food products and their components across every phase of production, processing, and distribution. This encompasses capturing and accessing detailed information concerning the history, origin, and current status of products at diverse points along the supply chain. Distinct from conventional record-keeping practices, modern traceability systems leverage advanced digital tools and integrated data management platforms to enable swift data sharing, secure storage, and real-time availability of information. Beyond addressing food safety by facilitating the rapid identification and removal of contaminated goods, traceability plays a pivotal role in verifying sustainability claims, ensuring regulatory compliance, and optimizing operational efficiency within increasingly complex supply networks (Reddy et al., 2023).

Technologies Enabling Traceability

Several cutting-edge technologies form the backbone of contemporary traceability systems in food logistics. Barcoding systems, though traditional, remain widely used due to their cost-effectiveness and reliability in identifying products and recording data at various supply chain points, even if they are limited in data capacity. More advanced, Radio Frequency Identification (RFID) technology offers superior data storage capabilities and operational advantages, such as non-line-of-sight scanning and the ability to read multiple items simultaneously, which significantly improves efficiency in logistics operations. Meanwhile, the Internet of Things (IoT) has revolutionized real-time monitoring by enabling the continuous collection of data on environmental conditions

like temperature, humidity, and transit times, crucial for maintaining the quality of perishable food items. Additionally, blockchain technology provides a decentralized and tamper-proof ledger system for recording traceability data, offering unparalleled transparency and security, and ensuring that data shared across the supply chain is both immutable and verifiable. Collectively, these technologies establish a robust digital ecosystem that enhances the precision, responsiveness, and collaborative capabilities of traceability systems (Jamkhedkar et al., 2021).

Operational Mechanisms of Traceability Systems

Implementing effective traceability systems necessitates the integration of several operational components working seamlessly together. The process begins with meticulous data capture and integration, whereby information is gathered at every stage of the supply chain, documenting essential details such as product identifiers, batch numbers, origin data, and handling conditions provided by farmers, processors, logistics providers, and retailers. Given the vast amounts of data involved, secure and scalable data storage solutions are imperative, with cloud computing offering substantial advantages in terms of accessibility, flexibility, and protection against data loss. Moreover, efficient traceability depends on well-established information sharing protocols among all actors within the supply chain (Austin & Wojcik, 2010). The use of standardized formats and guidelines, such as those set by GS1, facilitates interoperability and minimizes disruptions in data exchange. A critical feature of traceability systems is their capacity to support rapid recall and response mechanisms in the event of contamination or safety concerns, allowing organizations to swiftly isolate and remove affected products from circulation, thus protecting public health and mitigating financial and reputational risks. These operational mechanisms demand significant investments not only in technological infrastructure but also in workforce training and inter-organizational collaboration to ensure their consistent and reliable functionality (Huang et al., 2014).

Benefits of Traceability in Food Logistics

The adoption of comprehensive traceability systems yields numerous advantages for food supply chains across the globe. At the forefront is the assurance of food safety, as traceability allows for precise monitoring of products, thereby facilitating swift identification and removal of any items compromised by contamination or adulteration, ultimately reducing the scope and impact of recalls. Compliance with regulatory mandates set forth by entities like the European Food Safety Authority (EFSA) and the U.S. Food and Drug Administration (FDA) becomes more manageable through robust traceability practices, which are essential for enterprises operating in global markets. Furthermore, traceability systems enhance risk management by empowering organizations to address operational and reputational threats proactively, underpinned by documented evidence of diligence and compliance (Burke, 2019). From a market perspective, as consumers increasingly prioritize transparency, ethical sourcing, and sustainable practices, traceability emerges as a powerful marketing asset, strengthening consumer trust and fostering brand loyalty. Beyond these strategic benefits, traceability contributes significantly to operational efficiency by improving inventory management, minimizing waste, and refining demand forecasting, thereby optimizing the performance and sustainability of entire supply chains (Stevens, 2019).

Challenges and Barriers

Despite its considerable merits, the implementation of traceability systems is not without significant obstacles, particularly in developing and emerging economies. One of the primary barriers is the high cost associated with deploying advanced traceability technologies, which can be prohibitive for small and medium-sized enterprises (SMEs), thereby limiting widespread adoption and perpetuating disparities between large corporations and smaller actors in the supply chain. Technological integration poses another challenge, as incorporating sophisticated traceability solutions into pre-existing IT infrastructures often requires overcoming issues of compatibility and data harmonization across diverse platforms and legacy systems. Additionally, concerns regarding data privacy and proprietary information discourage some stakeholders from fully engaging in transparent data sharing, due to fears of competitive disadvantage, legal exposure, or potential damage to corporate reputation. Compounding these challenges is the lack of standardized regulations and practices across different countries and sectors, resulting in fragmented systems and operational inefficiencies. Addressing these barriers calls for collaborative policy development, financial incentives to support technological adoption, and comprehensive training programs to build the necessary technical expertise across all levels of the supply chain (Boutros et al., 2014).

Conclusion

Traceability stands as a cornerstone of modern food logistics, serving as a vital mechanism for safeguarding food safety, enhancing supply chain resilience, and cultivating consumer trust. As food supply networks grow ever more complex and interconnected, the importance of reliable, technology-driven traceability systems cannot be overstated. Although challenges persist, particularly in the context of resource constraints and infrastructural limitations in emerging economies, the strategic value of traceability as both a regulatory obligation and a competitive advantage is clear and compelling. This paper has highlighted that investing in traceability

infrastructure, fostering collaborative industry initiatives, and pursuing regulatory alignment are essential for securing the future of sustainable and safe food logistics, ensuring that the journey from farm to fork is transparent, reliable, and worthy of consumer confidence.

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Comparison of Composition and Bioactive Properties of Garlic from Gaziantep and Kahramanmaraş

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Abstract

Garlic (*Allium sativum* L.) belongs to the Liliaceae family and is a vegetable of global economic importance due to its distinctive flavour and positive health effects. It is utilised as an essential component in both traditional and modern medicine. In this study, garlic cultivated in the Gaziantep and Kahramanmaraş regions was analysed. There is a lack of detailed studies in the literature comparing the general composition and bioactive properties of garlic from these two regions. The analyses encompassed moisture and protein content, colour characteristics, antioxidant capacity (measured through DPPH, ABTS, CUPRAC, and iron ion chelating capacity), and total phenolic content. Additionally, the sugar profile was assessed via the HPLC-RID method, the amino acid profile using HPLC-PDA, and total sulfur compounds along with allicin content were analysed. The amino acids identified in garlic samples included aspartic acid, glutamic acid, asparagine, serine, glutamine, histidine, glycine, threonine, arginine, tyrosine, cysteine, valine, methionine, tryptophan, phenylalanine, isoleucine, leucine, and proline. The total amino acid content was found to be 488.81 mg/100 g in Gaziantep garlic, whereas it was 417.34 mg/100 g in Kahramanmaraş garlic. In both regions, arginine was identified as the dominant amino acid. The amount of allicin in garlic grown in the Gaziantep region was measured at 2.51 mg/g, with a total sulfur compound amount of 7.84 mg/g. In garlic from the Kahramanmaraş region, the allicin content was measured at 2.37 mg/g, while the total sulfur compound amount was 6.58 mg/g. The findings provide vital insights into the nutritional and functional value of garlic by highlighting the differences in composition and bioactive properties of garlic cultivated in different regions.

Key Words: *Allium sativum L., bioactive properties, antioxidant capacity, allicin, HPLC*

Gaziantep ve Kahramanmaraş Sarımsağının Bileşim ve Biyoaktif Özelliklerinin Karşılaştırılması

Özet

Liliaceae familyasına ait olan sarımsak (*Allium sativum L.*), kendine özgü aroması ve sağlık üzerindeki olumlu etkileri nedeniyle dünya çapında ekonomik öneme sahip bir sebzedir. Geleneksel ve modern tıpta önemli bir bileşen olarak değerlendirilmektedir. Bu çalışmada, Gaziantep ve Kahramanmaraş yörelerinde yetişen sarımsaklar incelenmiş olup, literatürde bu iki yöreye ait sarımsakların genel bileşimi ve biyoaktif özelliklerini karşılaştıran ayrıntılı bir çalışma bulunmamaktadır. Bu eksikliği gidermek amacıyla kapsamlı analizler gerçekleştirilmiştir.Analizler kapsamında; nem ve protein miktarı, renk özellikleri, antioksidan kapasitesi (DPPH, ABTS, CUPRAC ve demir iyonlarını şelatlama kapasitesi ile ölçülmüştür), toplam fenolik madde miktarı belirlenmiştir. Ayrıca, HPLC-RID yöntemi ile şeker profili, HPLC-PDA yöntemi ile amino asit profili, toplam sülfürlü bileşik ve allisin miktarı analiz edilmiştir.Sarımsak örneklerinde aspartik asit, glutamik asit, asparajin, serin, glutamin, histidin, glisin, treonin, arjinin, tirozin, sistein, valin, metiyonin, triptofan, fenilalanin, izolösin, lösin ve prolin amino asitleri belirlenmiştir. Toplam amino asit miktarı Gaziantep sarımsağında 488,81 mg/100 g, Kahramanmaraş sarımsağında ise 417,34 mg/100 g olarak saptanmıştır. Her iki yörede de baskın amino asidin arjinin olduğu tespit edilmiştir.Gaziantep yöresinde yetişen sarımsaklarda allisin miktarı 2,51 mg/g, toplam sülfürlü bileşik miktarı ise 7,84 mg/g olarak belirlenmiştir. Kahramanmaraş yöresinde yetişen sarımsaklarda ise allisin miktarı 2,37 mg/g, toplam sülfürlü bileşik miktarı 6,58 mg/g olarak saptanmıştır.Elde edilen bulgular, farklı bölgelerde yetişen sarımsakların bileşimi ve biyoaktif özellikleri açısından farklılıklarını ortaya koyarak, sarımsağın besinsel ve fonksiyonel değerine yönelik önemli bilgiler sunmaktadır.

Anahtar Kelimeler: *Allium sativum L., biyoaktif özellikler, antioksidan kapasite, allisin, HPLC*

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Giriş

Sarımsak (*Allium sativum* L.), *Allium* cinsine ait bir türdür. Bu cins, fizyolojik olarak aktif sekonder metabolitler içeren sarımsak, soğan, arpacık soğanı, pırasa ve frenk soğanı gibi yüzlerce türü kapsamaktadır. Sarımsak tarih boyunca "Rus penisilini", "doğal antibiyotik" ve "bitkisel tılsım" gibi çeşitli unvanlarla anılmıştır (Lidiková ve ark., 2023). Sarımsak, içerdiği biyoaktif bileşenler nedeniyle hem geleneksel tıpta hem de modern tıbbi araştırmalarda önemli bir yer tutmaktadır. Yapılan çeşitli çalışmalar, sarımsağın güçlü antikanser, antimikrobiyal, antialerjik ve antioksidan özellikler taşıdığını ortaya koymuştur (Iciek ve Kwiecień, 2009; Rana ve ark., 2011). Sarımsağın farmakolojik etkileri oldukça çeşitlidir. Antibakteriyel aktivitesi sayesinde patojen mikroorganizmalara karşı etkili bir koruma sağlamakta, kan lipit düzeylerini düşürerek kardiyovasküler sağlığı desteklemekte ve antiinflamatuar etkisi ile kronik enflamasyonu azaltabilmektedir. Bunların yanı sıra, ateroskleroz gelişimini önleme potansiyeli, nöronal koruma sağlama yeteneği ve kalp sağlığı üzerindeki olumlu etkileri gibi biyolojik aktiviteleri, sarımsağı fonksiyonel bir gıda ve terapötik ajan olarak öne çıkarmaktadır (Iciek ve Kwiecień, 2009; Rana ve ark., 2011). Sahip olduğu çok sayıda biyoaktif bileşenin yanı sıra, özellikle tıbbi etkileri yüksek olan organosülfürlü bileşiklerden biri olan allisin, bu biyolojik aktivitelerin ortaya çıkmasında temel rol oynamaktadır (Mollica ve ark., 2018). Sarımsak, çeşitli biyoaktif bileşikler içermektedir (Jang ve ark., 2018). Bu bileşikler arasında organosülfür bileşikleri, allisin, diyalil sülfürler, diyalil disülfür, diyalil trisülfür ve S-alil-sistein sülfoksit (alliin) yer almaktadır. Ayrıca saponinler, fenolik bileşikler, amino asitler, uçucu yağlar, vitaminler, mineraller (germanyum, selenyum, kalsiyum ve demir), enzimler ve bağışıklık modüle edici polisakkaritler de sarımsakta bulunan önemli bileşenlerdendir (Qiu ve ark., 2020; Sasmaz ve ark., 2022; Shang ve ark., 2019).
Türkiye'de sarımsak üretimi yıllara göre değişiklik göstermekle birlikte, Türkiye İstatistik Kurumu (TÜİK) 2023 verilerine göre, en fazla sarımsak üretimi sırasıyla Kastamonu, Gaziantep, Kahramanmaraş, Aksaray ve Tokat illerinde gerçekleşmiştir (TUİK, 2023). Gaziantep ve Kahramanmaraş yörelerinde yetişen sarımsakların bileşimleri ve biyoaktif özellikleri karşılaştırmalı olarak incelenmemiştir. Bu çalışmada, her iki yöreye ait sarımsakların nem ve protein içeriği, renk özellikleri, antioksidan kapasiteleri (DPPH, ABTS, CUPRAC, demir iyonlarını şelatlama), toplam fenolik madde miktarı, şeker ve amino asit profilleri (HPLC-RID ve HPLC-PDA), toplam sülfürlü bileşik ve allisin içerikleri analiz edilerek kapsamlı bir karakterizasyon yapılmıştır. Bu sayede, bölgesel farklılıkların sarımsağın biyoaktif özellikleri üzerindeki etkisi değerlendirilmiştir.

Materyal ve Yöntem

Kimyasallar

Metanol (HPLC grade) ve sodyum karbonat Merck (Darmstat, Almanya) firmasından; psülfürlü bileşikler (L-(+)-alliin, allisin, SAC ve GSAC), şekerler (sakkaroz, glikoz, fruktoz), Sigma Chemical Co. (St. Louis, ABD) firmasından temin edilmiştir. DPPH (2,2-difenil-1-pikrilhidrazil), ABTS [2,2-azinobis-(3-etil-benzotiazolin-6-sülfonik asit)], 3-MPA (3-merkaptopropionik asit), FMOAC (9-Florenilmetoksikarbonil), OPA(o-fitalaldehit) ve Troloks ((+/-)-6-hidroksi-2, 5, 7, 8-tetrametil-kroman-2-karboksilik asit) Sigma-Aldrich Chemical Co. (St. Louis, ABD) firmasından ve etanol Riedel de Haen Co. (Seelze, Almanya) firmasından temin edilmiştir. HPLC analizlerinde mobil fazların hazırlanmasında Elga Purelab Option-Q marka saf su cihazından sağlanan 18.2 MΩ-cm ultra saf su kullanılmıştır. Standart çözeltiler ve diğer hassas çözeltiler günlük olarak hazırlanmıştır.

Materyal

Çalışmada kullanılan sarımsak (*Allium sativum* L.) örnekleri, Türkiye'nin önemli sarımsak üretim bölgelerinden olan Kahramanmaraş ve Gaziantep illerinden temin edilmiştir. Kahramanmaraş örnekleri, Kahramanmaraş ilinin Pazarcık ilçesindeki yerel bir pazardan; Gaziantep örnekleri ise Gaziantep ilinin Araban ilçesinden sağlanmıştır.

Nem ve kuru madde miktarı

Örneklerin nem oranları AOAC (1997)'de belirtilen metoda göre yapılmıştır. Kısaca darası alınan bir petri kutusuna yaklaşık 5 g ± 0,1 ağırlığında örnek tartılmış ve 105 ± 2°C'deki etüvde sabit ağırlığa gelinceye kadar kurutma işlemine tabi tutulmuştur.

Renk özelliklerinin belirlenmesi

Renk ölçümlerinde Hunter Lab Scan (Hunter Associates Laboratory, Inc., Reston, VA, USA) cihazı kullanılarak L*, a*, b* değerleri kaydedilmiştir (Hojjati ve ark., 2012). 'L*' değeri parlaklığı (beyazlık veya açıklık koyuluk); '+a*' değeri kırmızı; '-a*' değeri yeşil; '+b*' değeri sarı ve '–b*' değeri mavi renkleri temsil etmektedir. Bu değerlere bağlı olarak aşağıdaki formüllere göre renk berraklığı (Chroma) ve renk tonu (Hue) değerleri de hesaplanmıştır.
Renk berraklığı = (a*2 + b*2)1/2
Renk tonu = Arctan (b*/a*).

Protein tayini

Ham protein içeriği otomatik yakma, damıtma ve titrasyon ünitesi (Vapodest 45s Gerhardt) kullanılarak Kjeldahl yöntemiyle belirlenmiştir. Titrasyon işleminde harcanan 0.1 N HCl miktarı saptanarak elde edilen değerler kullanılıp örneklerdeki protein miktarı hesaplanmıştır (AOAC International. 2007).

Antioksidan Kapasitenin ve Toplam Fenolik Madde Miktarının Belirlenmesi Antioksidan aktivite analizleri

Sarımsak örneklerinin antioksidan aktiviteleri dört farklı yöntemle değerlendirilmiştir. Serbest radikalleri önleme yeteneğini ölçebilen DPPH (2,2, difenil 1-pikri hidrazil) kullanılarak ve metanol içerisinde gerçekleşen reaksiyonun zamana karşı değişiminin 515 nm'de (Agilent –Cary 60) spektrofotometredeki ölçüm sonuçlarına göre yapılmıştır (Brand-Williams ve ark., 1995; Sanchez-Moreno ve ark. 1998; Kelebek ve ark. 2009).

ABTS yöntemi Saafi ve ark. (2009)'nın metoduna göre yapılmıştır. Bu yöntem için 7 mM ABTS (2,2'-Azino-bis 3-ethylbenzothiazoline-6-sulfonic asit) 2.45 mM potasyumbisülfat ile karıştırılmıştır karanlık ortamda 12-16 saat bekletilmiştir ve daha sonra bu solüsyon sodium asetat (pH 4.5) tamponu ile spektrofotometrede 734 nm dalga boyunda 0.70±0.01 absorbans olacak şekilde seyreltilmiştir. Daha sonra 20 µL örnek 2.98 mL hazırlanan tampon ile karıştırılmıştır. Absorbans 10 dakika sonra spektrafotometrede 734 nm dalga boyunda ölçülmüştür. Elde edilen absorbans değerleri Trolox (10–100 µmol/L) standart eğim çizelgesi ile hesaplanmıştır. Elde edilen absorbans değerleri Trolox (10-100 µmol/L) standart eğim çizgisi ile hesaplanmıştır.

CUPRAC yöntemi Apak ve ark. (2004),'nin metoduna göre yapılacaktır. Bu yöntem için 1.0×10-2 M Bakır (II) klorür çözeltisi ($CuCl_2.2H_2O$), 1 M (pH=7) Amonyum asetat tamponu ve 7.5×10-3 M Neokuproin (2,9-dimetil-1,10-fenantrolin) çözeltisi hazırlanacaktır. Troloks antioksidan bileşiğinin stok çözeltisi ise 1.0×10-3 M konsantrasyonda olacak şekilde hazırlanacaktır. Bir cam tüp içerisine bakır (II) çözeltisi, neokuproin çözeltisi ve amonyum asetat tamponundan sırasıyla 1'er ml eklenecektir. Üzerine örneğin katı veya sıvı olma durumuna (x) göre (katı ise 0.5 ml, sıvı ise 0.3 ml) antioksidan çözeltisi ve (1.1-x) mL distile su ilave edilip tüpler iyice çalkalanacaktır. Toplam hacim 4.1 ml olacak şekilde hazırlanan çözeltiler oda koşullarında ağzı kapalı olarak 30 dakika boyunca bekletilecek ve süre sonunda içinde örnek bulunmayan referans çözeltiye karşı 450 nm'de absorbans değerleri ölçülecektir. Elde edilen absorbans değerleri Trolox standart eğim tablosu ile hesaplanarak sonuçlar mmol trolox/g cinsinden ifade edilecektir.

Örneklerin demir iyonlarını şelatlama kapasiteleri, analizi için öncelikle 2 mL örnek çözeltisi ile 0.1 mL 1 mmol/L $FeCl_2 \cdot 4H_2O$ çözeltisi karıştırılarak 30 dakika süreyle inkübasyona bırakılmıştır. Daha sonra karışıma 0.1 mL 5 mmol/L ferrozin çözeltisi ilave edilerek homojen bir şekilde karıştırılmış ve 10 dakika daha inkübasyon işlemi uygulanmıştır. İnkübasyon sonucunda örnek absorbansı, 562 nm dalga boyunda spektrofotometrik olarak ölçülmüştür.

Toplam Fenolik Madde Miktarı

Toplam fenolik madde analizi, Singleton ve ark. (1999) yöntemine göre yapılmıştır. 100 µl ekstrakt üzerine 7.5 ml distile su ilave edilmiş, 0.5 ml Folin-Ciocalteu reaktifi ilave edilmiş 3 dakika bekletilerek üzerine 1 ml %20'lik sodyum karbonat çözeltisi eklenmiştir ve daha sonra 0.9 ml distile su eklenmiş ve karıştırılmıştır. 1 saat oda koşullarında karanlıkta bekletilmiş ve UV spektrofotometre (Agilent Carry 60) ile 765 nm'de absorbans değerleri ölçülmüştür. Elde edilen absorbans değerleri gallik asit (31.25–500 ppm) standart eğim çizgisi ile hesaplanmış sonuçlar mg /100 gram TPC gallik asit eşdeğerleri (GAE) cinsinden ifade edilmiştir.

Şeker Bileşimi Analizi

Şeker bileşiminin belirlenmesi amacıyla, sarımsak örneklerinden 2 g alınarak üzerine 20 mL saf su ilave edilmiş ve 30 dakika süreyle ekstraksiyon işlemi uygulanmıştır (Sasmaz ve ark., 2022). Örnekler Shimadzu Prominence-i model HPLC cihazına enjekte edilerek analiz edilmiştir. Analizlerde, Bio-Rad firmasına ait Aminex HPX-87H (300 × 7.8 mm) kolonu kullanılmıştır. Taşıyıcı faz olarak 5 mM sülfürik asit çözeltisi kullanılmış ve fazın akış hızı 0.5 mL/dakika olarak ayarlanmıştır. Ayırma işlemi izokratik modda gerçekleştirilmiştir. Örneklerdeki sakkaroz, glikoz ve fruktoz miktarlarının belirlenmesi için refraktif indeks dedektörü (RID) kullanılmış ve kantitatif analizler dış standart yöntemi ile yapılmıştır. Bu kapsamda, her bir şeker bileşiği için beş farklı konsantrasyonda kalibrasyon çözeltileri hazırlanarak standart eğriler oluşturulmuştur.

Amino Asit Analizi

Amino asit analizleri için sarımsak örneklerinden 0.5 g tartılarak, üzerine 10 mL %0.1 N HCl çözeltisi ilave edilmiştir. Örnekler, geri soğutucu altında 110 °C'de 24 saat süreyle hidrolize edilmiştir. Hidroliz sonrasında elde edilen sıvı fazdan 2 mL alınarak 0.45 µm'lik membran filtreden geçirilmiş ve analiz için hazırlanmıştır.Filtre edilen örnekler, Shimadzu Prominence-i model HPLC cihazına enjekte edilmiştir. Analiz öncesinde, amino asitler 3-merkaptopropiyonik asit (3-MPA), ortoftalaldehit (OPA) ve 9-fluorenylmetil kloroformiat (FMOC) reaktifleri ile türevlendirilmiştir. Türevlendirilen örnekler, Shimadzu marka Shim-pack XR-ODS II kolonuna (2 µL enjeksiyon hacmi) enjekte edilerek amino asit miktarı saptanmıştır (Sasmaz ve ark., 2022).

Toplam sülfürlü Bileşiklerin ve Allisin Miktarının Analizi

Örnek ekstraksiyonu için Sasmaz ve ark. (2023) tarafından yürütülen yöntem uygulanmıştır. Analizler, Agilent 1260 LC sistemi ile entegre çalışan bir diyot dizin dedektörü (DAD) ve Agilent 6460 üçlü kuadrupol kütle spektrometresi (Agilent Technologies, Santa Clara, CA, ABD) kullanılarak gerçekleştirilmiştir. Sülfürlü bileşiklerinin tayininde, Phenomenex Luna C18 kolon (250 x 4.6 mm, 5 µm; Torrance, Kaliforniya, ABD) kullanılarak pozitif iyon modunda LC-DAD-ESI-MS/MS tekniği uygulanmıştır. Kromatografik ayırma işlemi için kolon sıcaklığı 25°C'de sabit tutulmuş ve 5 µL'lik enjeksiyon hacmi uygulanmıştır. Mobil faz olarak iki çözelti kullanılmıştır: çözücü A, su ve formik asit karışımından (99:1, v/v); çözücü B ise asetonitril ile çözücü A'nın 60:40 (v/v) oranında karıştırılmasıyla hazırlanmıştır analizde, gradient sistemi kullanılmıştır. Kütle spektrometresi analizlerinde elektrosprey iyonizasyon (ESI) kaynağı kullanılmış olup, nebülizör gaz basıncı 45 psi, kuru gaz akış hızı 15 L/dakika ve kuru gaz sıcaklığı 400°C olarak ayarlanmıştır.

Bulgular ve Tartışma

Kuru madde ve nem miktarının belirlenmesi

Gaziantep ve Kahramanmaraş illerinden temin edilen taze sarımsaklarda yapılan analizler sonucunda, kuru madde miktarları sırasıyla %28,93 ve %29,09, nem içerikleri ise %71,06 ve %70,91 olarak saptanmıştır (Tablo 1). Sasmaz ve ark. (2022) yaptıkları çalışmada Gaziantep ve Kastamonu taze sarımsaklarının nem içeriğini %60,3 ve %65,4 olarak belirlemişlerdir. Kutlu ve ark. (2018) Tunceli dağ sarımsağının özelliklerini araştırdıkları çalışmada, sarımsağın kuru madde miktarını %38,08 olarak saptamışlardır. Taze ve siyah sarımsağın fizikokimyasal ve antioksidan özelliklerinin araştırıldığı çalışmada, taze sarımsağın nem miktarı %64,21 olarak belirlenmiştir (Choi ve ark., 2014). Yapılan diğer çalışmalarda taze sarımsakların nem içeriklerinin %62,31 ile %72,42 arasında değiştiği bildirilmiştir (Kang ve ark., 2016, Resende Nassur ve ark., 2018).

Tablo 1. Sarımsakların genel bileşimleri

	Gaziantep	**Kahramanmaraş**
Nem (%)	71,06±0,57	70,91±0,41
Kuru madde(%)	28,93±0,57	29,09±0,41
Protein (%)	6,78±0,10	6,36±0,17
Renk Parametreleri		
L*	82,71±0,21	77,45±1,72
a*	1,7±0,06	2,32±0,15
b*	14,32±0,73	15,78±1,91
C	14,75±0,15	15,95±1,87
h*	96,90±0,09	98,49±1,08
Şeker Bileşimi (mg/kg)		
Sakkaroz	1276,51±1,32	938,61±1,85
Glikoz	1055,70±0,83	895,58±3,62
Fruktoz	477,17±0,12	463,00±2,53
Toplam şeker	2809,39±2,28	2298,15±5,01

Protein miktarı

Gaziantep ve Kahramanmaraş taze sarımsaklarının protein miktarı Tablo 1'de verilmiş ve protein içerikleri sırasıyla %6,78 ve %6,36 olarak saptanmıştır. Sasmaz ve ark. (2022) yaptıkları çalışmada Gaziantep ve Kastamonu taze sarımsaklarının protein miktarını %7,5 ve %6,8 olarak belirlemişlerdir. Sasaki ve ark. (2007) taze sarımsağın protein miktarını %8,4 olarak, Liu ve ark. (2018) ise %5,32 olarak bildirmiştir. Sarımsakların protein içerikleri genel olarak değerlendirildiğinde Gaziantep ve Kahramanmaraş yörelerine ait sarımsakların protein içeriklerinin literatür verileriyle uyumlu olduğu ve Gaziantep yöresinin protein içeriğinin Kahramanmaraş yöresine kıyasla yüksek olduğu saptanmıştır.

Renk özellikleri

Renk, gıda seçimi ve kabul edilebilirliği üzerinde önemli bir etkiye sahiptir ve genellikle gıda kalitesinin bir göstergesi olarak lezzet, güvenlik ve besin değeri ile ilişkilendirilmektedir (Andrés-Bello ve ark., 2013; Hutchings, 2016). Bir nesnenin kabul/reddinin %62-90 oranında renge bağlı oluştuğu ve tüketicilerin satın alma kararlarını bir ürünle temasın ilk 90 saniyesinde oluşan izlenimlere dayandığı bildirilmiştir (Brennan, 2006). Taze sarımsakların L*, a*, b*, C ve h değerleri Tablo 1'de verilmiştir. L* değeri parlaklığı (beyazlık veya koyuluk); +a*' değeri kırmızı; -a*' yeşil; +b*' değeri sarı ve –b' değeri mavi renkleri temsil etmektedir. Gaziantep ve Kahramanmaraş yörelerinden temin edilen taze sarımsakların renk parametrelerinden L* değeri sırasıyla 82,71 ve 77,45 olarak belirlenmiştir. Renkteki kırmızılığın göstergesi olan a* değeri 1,70 ve 2,32 sarılığın göstergesi olan b* değeri, 14,75 ve 15,95, C değeri 14,75 ve 15,95, h değeri ise 96,9 ve 98,49 olarak tespit edilmiştir (Tablo 1).

Antioksidan aktivite

Gıdalardaki doğal bileşiklerin antioksidan aktivitelerini belirlemek için çeşitli yöntemler bulunmaktadır (Kim, Jung ve ark., 2012). Gaziantep ve Kahramanmaraş taze sarımsaklarının antioksidan kapasitesi DPPH, ABTS, CUPRAC ve demir iyonlarını şelatlama kapasitesi olmak üzere dört farklı yöntemle belirlenmiş ve elde edilen veriler Tablo 2'de verilmiştir.

Bitkilerin ve ekstraktların radikal temizleme kapasitesinin belirlenmesinde kullanılan en yaygın yöntemlerden biri 2,2-difenil-1-pikrilhidrazil (DPPH) analizidir. Bu yöntem, uygulanması kolay, tekrarlanabilirliğinin yüksek ve ekonomik olmasıyla bilinmektedir. DPPH yöntemi, DPPH radikalinin antioksidanlar tarafından bir redoks reaksiyonuna bağlı olarak süpürülmesi temeline dayanmaktadır (Carmona-Jiménez ve ark., 2014). Gaziantep taze sarımsağının DPPH yöntemiyle saptanan antioksidan kapasitesi 174,54 µmol Trolox/100g KA, Kahramanmaraş taze sarımsağının ise 146,91 µmol Trolox/100g KA olarak saptanmıştır (Tablo 2).

Tablo 2. Sarımsak örneklerinin antioksidan kapasite ve toplam fenolik madde miktarı sonuçları

	Gaziantep	Kahramanmaraş
Toplam Fenolik Madde[1]	276,97±3,86	252,91±1,79
DPPH[2]	174,54±3,09	146,70±3,12
ABTS[2]	312,15±5,32	307,62±5,02
CUPRAC[3]	62,85±0,81	58,81±1,16
Demir İyonlarını Şelatlama Kapasitesi[4]	63,22±0,02	62,54±0,17

[1] mg GAE /100 g KA, [2] µmol Trolox /100 g KA, [3] mmol Trolox/100 g KA,[4]mg EDTA/100 g KA

ABTS (2,2′-azinobis-3-etilbenztiazolin-6-sülfonik asit) yöntemi, ilk olarak Miller ve arkadaşları (1993) tarafından bildirilmiş olup, ABTS'nin hidrojen persülfat ile oksidasyonuyla oluşturulan, ABTS+ radikalinin, bir antioksidanı stabilize etme yeteneğine dayanmaktadır (Londoño, 2012). ABTS yöntemiyle saptanan Gaziantep taze sarımsağının antioksidan kapasitesi 312,15 µmol Trolox/100g KA, Kahramanmaraş taze sarımsağının ise 307,62 µmol Trolox/100g KA olarak belirlenmiştir. CUPRAC (Bakır II iyonu indirgeme esaslı antioksidan kapasite) yönteminde, 2,9-dimetil-1,10- fenantrolin (Neokuproin-Nc)'in Cu(II) ile oluşturduğu bakır(II)-neokuproin kompleksinin (Cu(II)-Nc) antioksidan bileşikler varlığında 450 nm'de maksimum absorbans veren bakır(I)-neokuproin [Cu(I)-Nc] şelatına indirgenme yeteneğinden yararlanılarak bileşiklerin antioksidan kapasiteleri ölçülmektedir (Apak ve ark., 2014). Gaziantep taze sarımsağında CUPRAC yöntemiyle saptanan antioksidan kapasite 62,85 mmol Trolox/100 g KA, Kahramanmaraş taze sarımsağının ise 58,81 mmol Trolox/100 g KA olarak belirlenmiştir (Tablo 2). Demir iyonlarını şelatlama yöntemiyle saptanan antioksidan kapasite ise Gaziantep yöresinde yetişen sarımsaklarda 63,22 mg EDTA/100 g KA, Kahramanmaraş yöresinde yetişen sarımsakların ise 62,54 mg EDTA/100 g KA olarak saptanmıştır (Tablo 2).

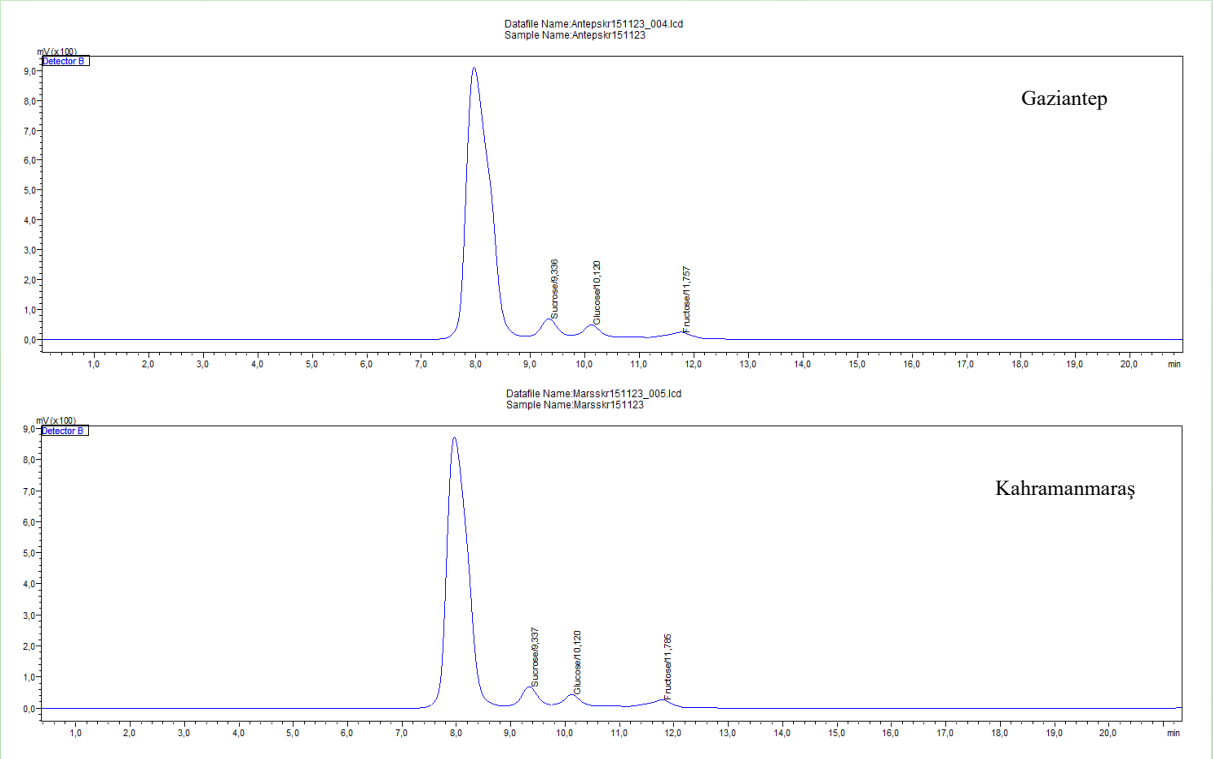
Toplam fenolik madde miktarı

Fenolik bileşikler, bitkilerde bulunan ve sağlık için faydalı olan doğal bileşiklerdir (Amoako ve Awika, 2016). Bu bileşiklerin, antioksidan ve antiinflamatuar gibi birçok biyolojik fonksiyona sahip olduğu bilinmektedir (Tavan ve ark., 2023). Fenolik bileşiklerin insan sağlığı üzerindeki potansiyel faydaları göz önüne alındığında, bu bileşiklerin gıda maddeleri ve ilaç ürünlerinde biyoaktif bileşen olarak kullanımı büyük ilgi görmüştür (Tavan ve ark., 2023). Gaziantep sarımsaklarının toplam fenolik madde miktarı 276,97 mg GAE/100 g KA, Kahramanmaraş sarımsaklarında ise 252,91 mg GAE/100 g KA olarak tespit edilmiştir (Tablo 2, Şekil 4). Yapılan bir çalışmada sarımsakta fenolik bileşiklerin toplam miktarının 3,4 ile 10,8 mg GAE/g arasında değiştiği ve ortalama 6,5 mg GAE/g olduğu bildirilmiştir (Qiu ve ark., 2020). Bir diğer çalışmada ise farklı solventler (metanol, hekzan ve etil asetat) ve farklı sürelerde (35, 50 ve 65 dakika) yapılan ekstraksiyonlar ile taze sarımsaklardaki toplam fenolik madde içeriğinin 38,57 ile 60,38 mg GAE/100g arasında değiştiği ve en yüksek içeriğe 50 dakikalık ekstraksiyon süresinde ve metanol kullanılarak ulaşıldığı bildirilmiştir (Awan ve ark., 2019). Bir diğer çalışmada ise taze sarımsaklardaki toplam fenolik madde miktarı 98 mg GAE/100g olarak belirlenmiştir (Bozin ve ark., 2008). Elde edilen veriler doğrultusunda çalışmamızda belirlenen TFM miktarının Qiu ve ark. (2020)'nin tespit ettiği TFM miktarından düşük, Awan ve ark., (2019) ve Bozin ve ark., (2008)'in çalışma verilerinden ise yüksek olduğu gözlenmiştir. Bunun nedeninin sarımsakların çeşidine, yetiştirilme yörelerine, mevsim koşullarına ve yetiştirme koşullarından (toprak, gübreleme ve sulama vb.) kaynaklı olabileceği düşünülmektedir.

Şeker profili

Taze sarımsağın %26-30'unu karbonhidratlar oluşturmaktadır (Darbyshire ve Henry, 1981). Polisakkaritler, sarımsağın ana bileşenlerindendir ve son yıllarda yapılan klinik çalışmalar, sarımsak polisakkaritlerinin antibakteriyel, antiinflamatuar, antidiyabetik, antitümör ve antiaging (yaşlanmayı engelleyici) potansiyele sahip olduğunu göstermektedir (Li ve ark., 2017). Tablo 1'de her Gaziantep ve Kahramanmaraş yörelerinden temin edilen taze sarımsaklarda belirlenen sakkaroz, glikoz ve fruktoz miktarları verilmiştir. Şekil 1'de belirlenen bileşiklere ait HPLC-RID kromatogramı, verilmiştir. İki yöreden de temin edilen taze sarımsaklarda baskın şeker

sakkaroz olarak saptanmış ve bunu miktarsal olarak fruktoz ve glikozun izlediği tespit edilmiştir. Gaziantep yöresinden temin edilen taze sarımsağın toplam şeker içeriği 2809,39 mg/kg, Kahramanmaraş yöresinden temin edilen taze sarımsağın ise 2298,15 mg/kg olarak tespit edilmiştir (Tablo 1). Bu bulgular, Gaziantep yöresi sarımsaklarının, Kahramanmaraş yöresi sarımsaklarına göre daha yüksek toplam şeker içeriğine sahip olduğunu göstermektedir.Gaziantep ve Kahramanmaraş yöresi taze sarımsaklarının sırasıyla sakkaroz miktarı 1276,51 mg/kg ve 938,61 mg/kg, glikoz miktarı 1055,70 ve 895,58 mg/kg ve fruktoz miktarı ise 477,14 ve 463,00 mg/kg olarak belirlenmiştir. Gaziantep yöresine ait sarımsakların şeker içeriklerinin Kahramanmaraş yöresi sarımsaklarından yaklaşık 1,2 kat yüksek olduğu tespit edilmiştir. Petropoulos ve ark. (2018), Yunanistan'da yetiştirilen sarımsaklarda sakkarozun baskın şeker olduğunu ve miktarının 1,99 ile 3,29 g/100 g arasında değiştiğini rapor etmişlerdir. Bu çalışmada, toplam şeker içeriğinin %97'sini sakkaroz oluştururken, fruktoz daha düşük seviyelerde bulunmuştur. Ayrıca, incelenen genotiplerin sadece üçünde glikoz tespit edilmiştir. Sasmaz ve ark. (2022), taze sarımsaklarda toplam şeker miktarının 1519-1856 mg/100g arasında değiştiğini bildirmişlerdir.



Şekil 1. Gaziantep ve Kahramanmaraş yöresi taze sarımsakların şeker kromatogramı

Amino asit profili

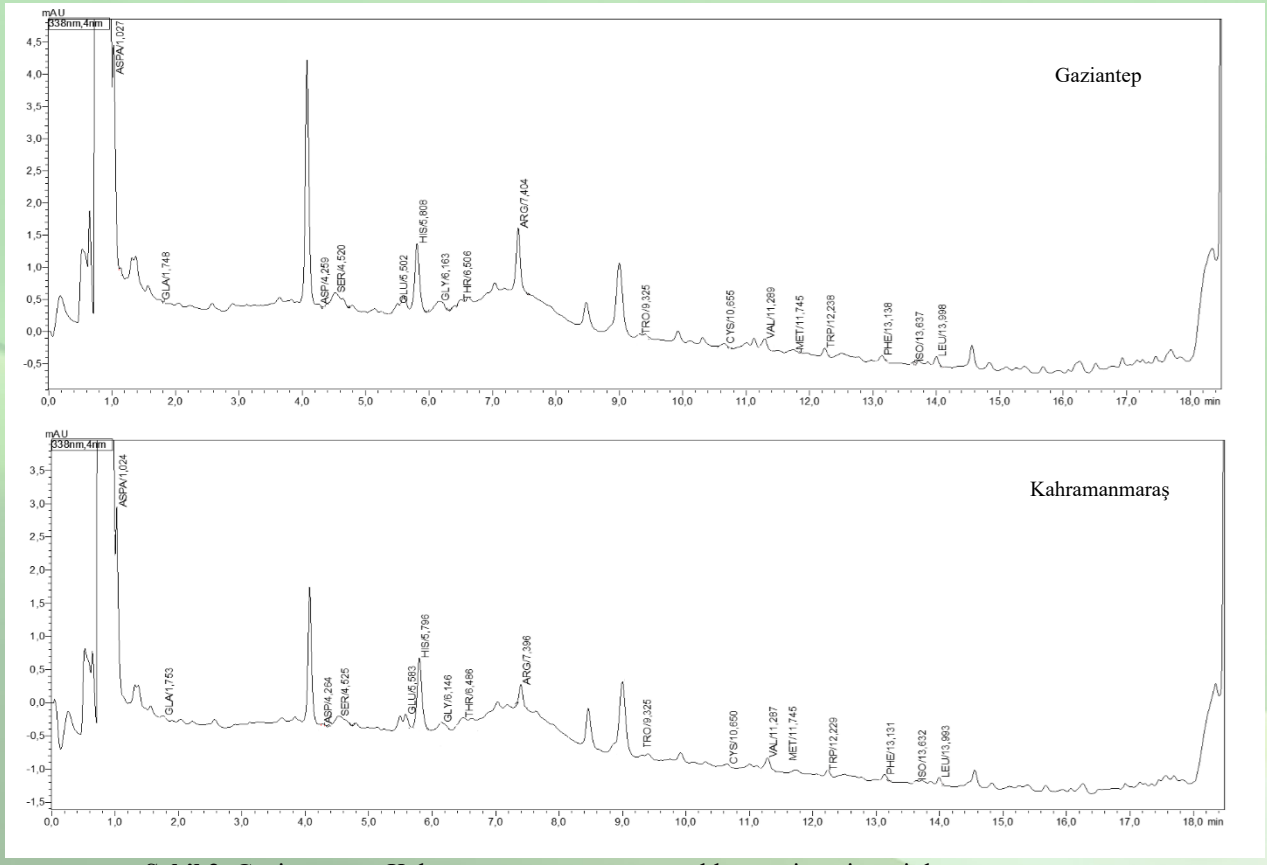
Sarımsak, antimikrobiyal özellikleri (Lanzotti ve ark., 2014), kanser önleyici potansiyeli (Dong ve ark., 2014), kardiyovasküler hastalıkların önlenmesi ve tedavisi (Katsuki, ve ark., 2006) ve antioksidan özellikleri (Fratianni ve ark., 2016) gibi sağlık yararları nedeniyle her geçen gün daha fazla ilgi görmektedir. Amino asitler insan vücudundaki en önemli bileşikler olarak kabul edilmektedir. Bu bileşikler yalnızca proteinlerin temel yapısal birimleri ve bir enerji kaynağı olmakla kalmaz, aynı zamanda nörotransmitterlerin, porfirinlerin, poliaminlerin ve nitrik oksitlerin biyosentezinde de önemli bir rol oynamaktadır (Guo ve ark., 2013). Sarımsaktaki amino asitlerin miktarı ve bileşimi, sarımsağın kalitesi ve besin değeri hakkında bilgiler sağlamaktadır. Yapılan çalışmalar, sarımsağın serbest amino asitler açısından zengin ve amino asit takviyesi için sağlıklı bir besin kaynağı olduğunu ortaya koymaktadır (Yongdoo ve ark., 2005; Lee ve Harnly 2005). Yapılan çalışmalarda sarımsakta baskın amino asittin arjinin olduğu bildirilmiştir (Liu, ve ark., 2018). Arjinin, tüm hücreler tarafından kullanılan yarı esansiyel bir amino asittir. Bu amino asit, ortalama olarak, normal insan diyetindeki toplam amino asitlerin %5-7'sini oluşturmaktadır (Pahlavani ve ark., 2017). Sarımsağın çeşidine ve yetiştirilme koşullarına bağlı olarak amino asit miktarı değişmektedir (Lee ve Harnly, 2005).

Gaziantep ve Kahramanmaraş yörelerinden temin edilen taze sarımsakların aminoasit profili ve miktarlarına ait veriler Tablo 3'de sunulmuştur. Her iki yörenin sarımsaklarında da 18 adet amino asit bileşiği saptanmıştır. Sarımsaklarda aspartik asit, glutamik asit, asparajin, serin, glutamin, histidin, glisin, treonin, arjinin, tirozin, sistein, valin, metiyonin, triptofan, fenilalanin, izolösin, lösin, prolin amino asitleri belirlenmiştir. Toplam amino asit miktarı Gaziantep sarımsağında 488,81 mg/100g, Kahramanmaraş sarımsağında ise 417,34 mg/100g olarak saptanmıştır. Gaziantep ve Kahramanmaraş sarımsaklarında baskın aminoasitin arjinin olduğu saptanmıştır. Gaziantep yöresi sarımsakların arjinin miktarı Kahramanmaraş yöresine göre yaklaşık 1,34 kat daha yüksek

içeriktedir. Arjinin sonrasında aspartik asit, glutamik asit, histidin ve tirozinin baskın amino asitler olduğu saptanmıştır. Bunlar dışında Gaziantep yöresi sarımsağının Kahramanmaraş taze sarımsağına göre asparajin miktarı 1,52 kat, glisin miktarı 1,45 kat, treonin miktarı 1,41 kat, tirozin miktarı 2,59 kat ve sistein miktarı ise 1,76 kat daha yüksek olduğu belirlenmiştir.

Tablo 3. Sarımsak örneklerine ait aminoasit miktarları

Alıkonma zamanı (dk)	Amax (nm)	Aminoasitler (mg/100 g)	Kısaltma	Gaziantep	Kahramanmaraş
1,02	338	Aspartik asit	ASPA	36,58±0,14	36,19±0,15
1,75	338	Glutamik asit	GLA	36,10±0,08	30,71±0,22
4,26	338	Asparajin	ASP	29,16±0,32	19,24±0,09
4,53	338	Serin	SER	19,17±0,11	22,77±0,16
5,58	338	Glutamin	GLU	26,30±0,17	21,37±0,18
5,80	338	Histidin	HIS	33,30±0,39	31,78±0,26
6,15	338	Glisin	GLY	21,95±0,21	15,11±0,04
6,18	338	Treonin	THR	22,92±0,31	16,26±0,10
7,64	338	Arjinin	ARG	100,67±0,08	74,89±0,04
9,40	338	Tirozin	TRO	42,22±0,13	16,27±0,19
10,65	338	Sistein	CYS	10,55±0,37	6,00±0,03
11,29	338	Valin	VAL	18,34±0,21	20,45±0,21
11,74	338	Metiyonin	MET	19,74±0,14	23,07±0,27
12,77	338	Triptofan	TRP	20,00±0,18	20,25±0,07
13,13	338	Fenilalanin	PHE	17,95±0,11	26,95±0,17
13,63	338	Izolösin	ISO	15,73±0,02	17,38±0,09
13,99	338	Lösin	LEU	14,70±0,15	15,07±0,09
17,55	262	Prolin	PRO	3,42±0,01	3,58±0,09
		Toplam		***488,81±1,16***	***417,34±0,95***



Şekil 2. Gaziantep ve Kahramanmaraş taze sarımsaklarına ait aminoasit kromatogramı

Kang (2016) yaptığı çalışmada, sarımsaklarda aspartik asit (23,64 mg/100 g), glutamik asit (17,35 mg/100 g), sistein (2,51 mg/100 g), histidin (111,46 mg/100 g), glisin (157,75 mg/100 g), treonin (2,17 mg/100 g), lizin (3,37mg/100 g), arjinin (30,78 mg/100 g), valin (216,47 mg/100 g), triptofan (203,03 mg/100 g) ve lösin (18,08 mg/100 g) amino asitlerini belirlemişlerdir. Liu ve ark. (2018) tarafından bir diğer çalışmada sarımsaklardaki lösin miktarı 9,2 mg/100 g, izolösin miktarı 14,08 mg/100 g, aspartik asit miktarı 14,66 mg/100 g, glutamik asit miktarı 60,5 mg/100 g, sistein miktarı 3,75 mg/ 100 g, triptofan miktarı 23,51 mg/100 g olarak belirlenmiştir. Bir diğer çalışmada, Liu ve ark., (2020) sarımsaktaki aspartik asit miktarını 30,9 mg/100 g kuru madde (KM), glutamik asit miktarını 32,7 mg/100 g KM, lizin miktarını 154 mg/100 g KM, arjinin miktarını 74,3 mg/100 g KM, valin miktarını 6,4 mg/100 g KM, triptofan miktarını 0,7 mg/100 g KM, lösin miktarını 2,7 mg/100 g KM olarak belirlemişlerdir. Lu, (2017) yaptığı çalışmada sarımsağın amino asit miktarını 19,43 mg/ g olarak belirlemişlerdir.

Toplam sülfürlü bileşik ve allisin miktarı

Sarımsağın insan sağlığı üzerine yararlı etkileri sülfürlü bileşiklere çoğunlukla da allisin (dialil tiyosülfinat, 3-prop-2- enylsulfinylsulfanylprop-1-ene) bileşiğine atfedilmiştir (Amagase, 2006; Okada ve ark., 2008). İnsan sağlığı için önemli bir bileşik olan allisin, sarımsağın biyoaktif ve ana fonksiyonel bileşenidir (Meriga ve ark., 2012; Liang ve ark., 2012). Sarımsaktaki allisin varlığı ve biyolojik özellikleri ilk olarak 1944'te Chester John Cavallito ve John Hays Bailey tarafından bildirilmiş ve allisin bileşiğine "sarımsağın kalbi" denilmiştir (Josling, 2007). LC/MS/MS yardımıyla toplam sülfürlübileşik ve allisin miktarı belirlenmiştir. Gaziantep ve Kahramanmaraş sarımsakları kullanılarak en yüksek allisin içeriğine sahip taze sarımsak belirlenmiştir. Gaziantep yöresinde yetişen sarımsak örneklerinde allisin miktarı 2,51 mg/g, toplam sülfürlü bileşik miktarı ise 7,84 mg/g olarak belirlenmiştir. Kahramanmaraş yöresinde yetişen sarımsak örneklerinde allisin miktarı 2,37 mg/g, toplam sülfürlü bileşik miktarı ise 6,58 mg/g olarak belirlenmiştir. En yüksek allisin ve toplam sülfürlü bileşik miktarına sahip taze sarımsağın Gaziantep yöresinde yetişen taze sarımsak olduğu tespit edilmiştir. Yapılan bir çalışmada sarımsağın gramı başına yaklaşık 2.5 ila 4.5 mg allisin içerdiği bildirilmiştir (Lawson ve Hunsaker 2018).

Tartışma

Bu çalışmada, Gaziantep ve Kahramanmaraş yörelerinde yetiştirilen taze sarımsakların fizikokimyasal özellikleri, biyoaktif bileşen içerikleri ve antioksidan kapasiteleri kapsamlı bir şekilde karşılaştırılmıştır. Elde edilen bulgular, her iki yöre sarımsaklarının önemli besin değerlerine ve fonksiyonel özelliklere sahip olduğunu, ancak bazı parametrelerde belirgin farklılıklar gösterdiğini ortaya koymuştur. Nem içerikleri açısından her iki yöre sarımsakları benzer özellikler göstermiştir. Ancak, Gaziantep sarımsaklarının protein içeriği (%6.78) Kahramanmaraş sarımsaklarına (%6.36) göre daha yüksek bulunmuştur. Antioksidan aktivite sonuçları, her iki yöre sarımsaklarının güçlü antioksidan kapasiteye sahip olduğunu göstermiştir. Şeker profili analizleri, Gaziantep sarımsaklarının toplam şeker içeriğinin (2809.39 mg/kg) Kahramanmaraş sarımsaklarından (2298.15 mg/kg) yaklaşık %22 daha yüksek olduğunu göstermiştir. Amino asit profillerinde ise her iki yöre sarımsaklarında arjininin baskın amino asit olduğu belirlenmiştir. Gaziantep sarımsaklarının toplam amino asit içeriği (488.81 mg/100g), Kahramanmaraş sarımsaklarına (417.34 mg/100g) göre belirgin şekilde yüksek bulunmuştur.
Sülfür bileşikler açısından yapılan analizler, Gaziantep sarımsaklarının hem allisin (2.51 mg/g) hem de toplam sülfürlü bileşik (7.84 mg/g) içeriğinin Kahramanmaraş sarımsaklarına göre daha yüksek olduğunu göstermiştir.
Sonuç olarak, bu çalışma Gaziantep ve Kahramanmaraş yörelerinde yetiştirilen sarımsakların besin değerleri ve biyoaktif özellikleri açısından bazı farklılıklar gösterdiğini ortaya koymuştur. Gaziantep sarımsakları genel olarak daha yüksek protein içeriği, antioksidan kapasite, şeker ve amino asit içeriği ve toplam sülfürlü bileşik içeriği ile dikkat çekmiştir.

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Effect of infusion time on the biochemical composition of *Tamarindus indica*

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Abstract

Tamarind (*Tamarindus indica* L.), an evergreen tree from the Fabaceae (Leguminosae) family, has garnered attention in both scientific research and traditional medicine due to its rich antioxidant content, natural sugars, organic acids, and phytochemical compounds. Interest in herbal infusions and their applications is growing, especially regarding their bioactive properties and potential health benefits. However, studies on the effects of infusion parameters, such as temperature and duration, on tamarind infusions remain limited in the literature. In this study, we investigated the effect of infusion time (3, 6, and 12 minutes) on the total phenolic content (TPC), antioxidant activity, organic acid profile, and sugar composition of tamarind fruit extract. We evaluated the changes in the antioxidant potential of the samples based on infusion duration using two different methods: DPPH and ABTS, while organic acids were analyzed by HPLC-PDA and sugar composition by HPLC-RID. The highest antioxidant activity, determined by DPPH and ABTS assays, was observed at the 12-minute infusion time, with values of 6780.95 and 7431.33 µmol Trolox/L, respectively. The total phenolic content at this duration was recorded as 2832.02 mg GAE/L. Tamarind infusions contained citric, malic, and tartaric acids as organic acids, along with sucrose, glucose, and fructose as sugars. The highest concentrations of organic acids and sugars were found in the 12-minute infusion. Tartaric acid (51.82 g/L) was identified as the predominant organic acid, while glucose (30.47 g/L) was the most abundant sugar. These findings highlight the potential of tamarind fruit infusions as a promising alternative to conventional herbs. At the same time, their high antioxidant content and beneficial organic acid composition.

Key Words: *Tamarindus indica, Antioxidants, organic acids, Infusions, Sugar profile*

İnfüzyon süresinin *Tamarindus indica*'nın biyokimyasal bileşimi üzerine etkisi

Özet

Fabaceae (Leguminosae) familyasından yaprak dökmeyen bir ağaç olan demirhindi (*Tamarindus indica* L.), zengin antioksidan içeriği, doğal şekerleri, organik asitleri ve fitokimyasal bileşikleri nedeniyle hem bilimsel araştırmalarda hem de geleneksel tıpta dikkat çekmiştir. Bitkisel infüzyonlara ve uygulamalarına olan ilgi, özellikle biyoaktif özellikleri ve potansiyel sağlık yararları açısından giderek artmaktadır. Bununla birlikte, sıcaklık ve süre gibi infüzyon parametrelerinin demirhindi infüzyonları üzerindeki etkilerine ilişkin çalışmalar literatürde sınırlı kalmaktadır. Bu çalışmada, infüzyon süresinin (3, 6 ve 12 dakika) demirhindi meyve özütünün toplam fenolik içeriği (TPC), antioksidan aktivitesi, organik asit profili ve şeker bileşimi üzerindeki etkisi araştırılmıştır. İnfüzyon süresine bağlı olarak örneklerin antioksidan potansiyelindeki değişiklikleri iki farklı yöntem kullanarak (DPPH ve ABTS) değerlendirilmiştir, organik asitler HPLC-PDA ve şeker bileşimi HPLC-RID ile analiz edilmiştir. DPPH ve ABTS analizleri ile belirlenen en yüksek antioksidan aktivite, sırasıyla 6780,95 ve 7431,33 µmol Trolox/L değerleri ile 12 dakikalık infüzyon süresinde gözlenmiştir. Bu süredeki toplam fenolik içerik 2832,02 mg GAE/L olarak kaydedilmiştir. Demirhindi infüzyonları organik asit olarak sitrik, malik ve tartarik asitler ile şeker olarak sukroz, glukoz ve fruktoz içermektedir. En yüksek organik asit ve şeker konsantrasyonları 12 dakikalık infüzyonda bulunmuştur. Bu süre zarfında toplam fenolik içerik 2832,02 mg GAE/L olarak kaydedilmiştir. Demirhindi infüzyonları organik asit olarak sitrik, malik ve tartarik asitlerin yanı sıra şeker olarak sükroz, glukoz ve fruktoz içermektedir. En yüksek organik asit ve şeker konsantrasyonları 12 dakikalık infüzyonda bulunmuştur. Tartarik asit (51,82 g/L) baskın organik asit olarak belirlenirken, glikoz (30,47 g/L) en bol bulunan şeker olmuştur. Bu bulgular, demirhindi meyvesi infüzyonlarının geleneksel bitkilere umut verici bir alternatif olma potansiyelini vurgulamaktadır. Aynı zamanda, yüksek antioksidan içeriği ve faydalı organik asit bileşimine sahiptir.

Anahtar Kelimeler*: Tamarindus indica, Antioksidanlar, organik asitler, İnfüzyonlar, Şeker profili*

Giriş

Demirhindi (*Tamarindus indica* L.- *T. indica*), Fabaceae (Leguminosae) familyasının bir üyesidir ve Dünyada Hindistan, Bangladeş, Sri Lanka, Tayland ve Endonezya gibi Asya ülkeleri ile Afrika ve Amerika olmak üzere 50'den fazla ülkede yetişmektedir (Pal& Mukherjee, 2020). Orta ila büyük boyutlu, yaprak dökmeyen, 24 m yüksekliğe ve 7 m çevreye sahip bir ağaçtır ve meyve yaklaşık %55 pulp, %34 tohum ve %11 kabuk ve tohumu kaplayan lif tabakasından oluşmaktadır (Hemshekhar ve ark., 2011). Tohumlar çok sert, parlak, kırmızımsı veya morumsu kahverengi, meyvenin içine gömülmüş halde bulunmaktadır ve sert bir zar ve liflerle birbirlerine bağlanmaktadır (Şekil 1). Hindistan yılda yaklaşık 0.3 milyon ton *T. indica* yetiştirmektedir ve bunun yaklaşık %30-34'ünü tohum oluşturmaktadır. Meyve özü (pulp) furan türevleri, karboksilik asit, flobatannin, asetik, sitrik, formik, malik, süksinik asit, flavonoidler, pektin, şeker içermektedir ve pulp dünyanın birçok ülkesinde yaygın olarak tüketilmektedir. (Dhasade ve ark., 2009; Tril ve ark., 2014). Tohumlar, kampesterol, *β*-amirin, β-sitosterol, yağ asitleri, tanenler, şeker, musilaj ve polisakkaritler, kardiyak glikozitler ve fenolikler içermektedir (Dhasade ve ark., 2009, Yeasmen& Nazrul Islam, 2015; Ganesapillai ve ark., 2017). Kabuk ise tanenler, saponinler, glikozitler, peroksidaz ve lipitleri içermektedir (Dhasade ve ark., 2009). Polifenoller, örneğin flavonoidler ve fenolikler, bitkinin hemen hemen her bölümünde bulunmakta ve bu da *T. indica*'yı antioksidan içeriği yüksek bir gıda haline getirmektedir(Ganesapillai ve ark., 2017). Meyvenin besin kompozisyonu incelendiğinde protein ~%7.5, nem ~%15.50, yağ ~%3, karbonhidrat ~%70 ve lif ~%4.5 olarak belirlenmiştir (Sadiq ve ark., 2016). *T. indica*, antidiyabetik, hipolipidemik, hepatoprotektif, antimikrobiyal ve antiproliferatif özellikler gibi bildirilen bazı aktivitelere sahiptir (El-Siddig, 2006). Farooq ve ark. (2022) meyvenin posasının C vitamini ve şeker açısından çok zengin olduğunu tespit etmiştir. Bu nedenle şuruplarda, meyve suyu konsantrelerinde, turşularda ve et soslarında kullanılmaktadır. *T. indica*, başta düşük glisemik indekse sahip fruktoz ve hücresel enerji üretimi için temel kaynak olan glikoz olmak üzere, tatlı ve keskin lezzetine katkıda bulunan doğal şekerler açısından zengindir. Bu şekerler sadece enerji sağlamakla kalmaz, aynı zamanda meyvenin genel lezzetinde ve besin değerinde de rol oynamaktadır. Birçok farklı tarif olmasına rağmen genellikle meyve suyu, infüzyon veya salamura haline getirilmektedir (Katare ve Hakrovorty, 2019).

Meyve, karakteristik ekşi tadından sorumlu olan tartarik asit de dahil olmak üzere çeşitli organik asitler içermektedir. Tartarik asit, özellikle *Aspergillus flavus* gibi türlere karşı antifungal özellikleriyle dikkat çekmektedir (Kachapulula ve ark., 2019). *T. indica*'da bulunan diğer organik asitler arasında, sindirime ve metabolik süreçlere yardımcı olarak sağlık üzerinde etkili olan sitrik asit ve malik asit içermektedir. *T. indica*, serbest radikallerin nötralize edilmesinde ve oksidatif stresin azaltılmasında önemli bir rol oynayan galik asit, ferulik asit, kafeik asit ve *p*-kumarik asit gibi fenolik asitler, apigenin, luteolin, kersetin, rutin ve naringenin gibi flavonoidler, C vitamini, *β*-karoten ve lutein gibi karotenoidleri içermektedir. *T. indica*'da tanımlanan diğer temel antioksidan bileşikler ise 2-hidroksi-3',4'-dihidroksiasetofenon, metil 3,4-dihidroksibenzoat ve oligomerik proantosiyanidinlerdir (OPC'ler) (Waqas ve ark., 2013). Bu bileşikler, DPPH serbest radikal temizleme yöntemi de dahil olmak üzere çeşitli analizlerle belirlenen *T. indica*'nın genel antioksidan aktivitesine katkıda bulunmaktadır (Waqas ve ark., 2013). Ayrıca, mirisetin ve prosiyanidin B2 gibi flavonoidlerin varlığı antioksidan profilini daha da geliştirmektedir (Pratiwi ve ark., 2020).

Tamarindus indica, zengin antioksidan içeriği, doğal şekerleri, organik asitleri ve fitokimyasal bileşenleri sayesinde sağlığa birçok fayda sağlayan bir meyvedir. Geleneksel kullanımının yanı sıra, bu faydalar bilimsel araştırmalarla da desteklenmektedir. *T. indica* infüzyonları, özellikle metabolik ve kardiyovasküler hastalıkların yönetiminde destekleyici bir bileşen olarak değerlendirilen çeşitli sağlık yararlarıyla dikkat çekmektedir. Maekawa ve ark. (2022), *T. indica* yapraklarından elde edilen metanolik ekstraktların biyolojik sistemlerde antioksidan seviyelerini artırdığını ve oksidatif stresle ilişkili durumların yönetiminde potansiyel bir diyet takviyesi olarak kullanılabileceğini belirtmişlerdir. Ayrıca, *T. indica* posası infüzyonunun gastrointestinal sağlık üzerindeki etkileri incelenmiş; ülserlere karşı koruyucu etki gösterdiği ve mukozal savunma mekanizmalarını desteklediği rapor edilmiştir (Umar ve ark., 2023). *T. indica*'nın antidiyabetik etkileri de kapsamlı şekilde araştırılmıştır. Meher (2017) ile Purwaningsih ve ark. (2023) tarafından yürütülen çalışmalar, *T. indica* tohumları ve yapraklarından elde edilen ekstraktların diyabetik modellerde kan glikoz düzeylerini anlamlı ölçüde düşürebildiğini ve lipid profillerini iyileştirebildiğini göstermiştir. Bu etkilerin, içerdiği flavonoidler ve saponinler gibi biyoaktif bileşiklerin insülin duyarlılığını artırması ve lipid metabolizmasını düzenlemesiyle ilişkili olduğu düşünülmektedir. Etukudo ve ark. (2024) ise *T. indica*'nın özellikle oksidatif stres ve nörodejenerasyonla ilişkili durumlarda gösterdiği nöroprotektif etkileri vurgulamış; yapısında bulunan flavonoidlerin ve diğer fitokimyasalların, nöronal hücreleri hasardan koruma potansiyeline sahip olduğunu belirtmişlerdir.

T. indica infüzyonu, meyvenin sıcak suda bekletilerek hazırlanmasıyla elde edilen bir özüt veya çaydır. İnfüzyon ile, meyvenin biyoaktif bileşenleri suya geçmekte için sağlık açısından değerli bileşenler içermektedir: Fenolik bileşikler antioksidan ve anti-inflamatuar etkiler göstermekte, flavonoidler hücresel yaşlanmayı yavaşlatmakta ve bağışıklık sistemini güçlendirmekte, organik asitler (tartarik asit, sitrik asit) sindirimi desteklemekte ve bağırsak sağlığına fayda sağlamakta ve mineraller (potasyum, magnezyum, demir) ise kan basıncını düzenlemekte ve kas fonksiyonlarını desteklemektedir (Pratiwi ve ark., 2020; Etukudo ve ark., 2024). Ayrıca *T. indica* meyve özünden

elde edilen antioksidan bakımından zengin ekstraktlar, oksidatif stresle ilgili gen ifadesinin modülasyonuyla ilişkilendirilmiş ve oksidatif hasarla mücadeledeki rollerini daha da desteklemiştir (Razali ve ark., 2010). *T. indica* infüzyonu, antioksidanlar, anti-inflamatuar ajanlar ve diğer biyoaktif bileşiklerden oluşan zengin bileşimi sayesinde sağlığı geliştirmek için umut verici bir yol sunmaktadır. Çeşitli çalışmalardan elde edilen kanıtlar, oksidatif stres, inflamasyon, gastrointestinal sağlık ve metabolik bozuklukların yanı sıra yara iyileşmesi ve enfeksiyon yönetimindeki geleneksel uygulamaların yönetiminde potansiyel kullanımını desteklemektedir.
T. indica infüzyonları ve uygulanan sıcaklık ve süre gibi faktörlerin meyvenin yapısında bulunan ve infüzyon ile suya geçem önemli biyoaktif bileşikler üzerinde etkisi ile ilgili literatürde sınırlı çalışma bulunmaktadır. Bu çalışmada, *T. indica* meyve özünün TPC, antioksidan aktivite, organik asitler ve şeker kompozisyonu üzerine infüzyon süresinin (3, 6, 12 dakika) etkisi incelenmiştir. Örneklerin infüzyon süresine bağlı olarak antioksidan potansiyelinin ne şekilde değiştiği DPPH ve ABTS olmak üzere iki farklı yöntemle belirlenmiştir. Organik asitler HPLC-PDA ile, şeker kompozisyonu ise HPLC-RID kullanılarak değerlendirilmiştir.

Materyal ve Yöntem

1. Kimyasallar

Organik asitler, şeker standartları, 2,2-difenil-1-pikrilhidrazil (DPPH) ve Trolox Sigma-Aldrich Chemical Company'den ve Folin-Ciocalteu reaktifi Merck'ten satın alınmıştır. HPLC sisteminde referans standartlar olarak organik asitler için sitrik (77-92-9), malik asit (6915-15-7) ve tartarik asit (87-69-4), şeker analizi için sakkaroz (57-50-1), glukoz (50-99-7) ve fruktoz (57-48-7) Merck'ten satın alınmıştır.

2. İnfüzyonların hazırlanması

Demirhindi (*T. indica*) Adana'da yerel bir marketten satın alınmıştır. İnfüzyon çaylarda yaygın olarak kullanılan sıcaklık 85ºC ile 100ºC, infüzyon süresi ise 3-15 dakika arasındadır ve bu sıcaklık ve süreler daha önceki çalışmalarımızda da kullanılmış ve iyi sonuçlar elde edilmiştir (Kelebek, 2016; Uzlasir ve ark., 2020). Ayrıca, mevcut literatürden elde edilen koşullar da benzer sıcaklık ve süreler kullanılmıştır (Ariffin ve ark., 2011; Gan ve Ting, 2017; Pan ve ark., 2018; Xiao ve ark., 2017). *T. indica*'ların kabuk, meyve ve çekirdekleri ayrılmış ve infüzyonların hazırlanmasında meyve kısmı kullanılmıştır (Şekil 1).



(a) (b) (c) (d)

Şekil 1. *T. indica* meyve bölümleri (a: tüm meyve, b: kabuk, c: meyve özü (pulp) ve d: tohum)

Beş gram *T. indica* meyve özü tartılarak 250 mL'lik bir behere aktarılmış ve üzerine 100 °C'de 100 mL sıcak su eklenerek 3, 6 ve 12 dakika süreyle demlenmiştir. Elde edilen örnekler, 4 °C'de 15 dakika boyunca 6.500 rpm'de santrifüj edilmiş ve yüksek performanslı sıvı kromatografi (HPLC) analizi öncesinde 0,45 µm'lik membran filtre (Millipore) ile süzülmüştür. İnfüzyon işlemleri ve analizler, üç tekerrürlü olarak gerçekleştirilmiştir.

3. Antioksidan aktivite (AA) ve toplam fenolik madde (TFM) analizleri

3.1 Antioksidan aktivite (DPPH ve ABTS yöntemleri kullanılarak) analizleri

DPPH analizi, Brand-Williams ve ark. (1995) tarafından tanımlanan yönteme çeşitli modifikasyonlar uygulanarak gerçekleştirilmiştir. Kısaca, her bir ekstrakttan 200 µL alınarak 3,9 mL DPPH çözeltisi ile karıştırılmış ve karışım karanlık ortamda, oda sıcaklığında 1 saat süreyle inkübe edilmiştir. Ardından, absorbans değerleri UV-görünür spektrofotometre (Cary 60, Agilent, Malezya) kullanılarak 517 nm dalga boyunda ölçülmüştür. Antioksidan aktiviteler, bir kalibrasyon eğrisi yardımıyla hesaplanmış ve sonuçlar µmol Trolox/L cinsinden ifade edilmiştir.
ABTS radikal süpürme aktivitesi analizi, Re ve ark. (1999) tarafından belirtilen yönteme göre modifiye edilmiş otomatik ağartma yöntemi kullanılarak gerçekleştirilmiştir. İnhibisyon yüzdesi hesaplanmış ve sonuçlar µmol Trolox / L olarak ifade edilmiştir.

3.3 Toplam fenolik madde (TFM) analizi

TFM analizleri daha önce Singleton ve ark. (1999) tarafından belirtilen Folin-Ciocalteu reaktifi kullanılarak tespit edilmiştir. Kısaca, 200 µl infüzyon 0,5 ml Folin-Ciocalteu reaktifi ile 3 dakika boyunca karıştırılmış, ardından 2

ml %20 (w/v) sodyum karbonat eklenmiştir. Karışım daha sonra 765 nm'de absorbans ölçülmeden önce 30 dakika oda sıcaklığında bekletilmiştir. TFM miktarı, mg gallik asit eşdeğerleri (GAE) /L olarak ifade edilmiştir.

4. Organik asit ve şeker analizi

İnfüzyonlar, organik asit ve şeker profillerini tespit etmek ve miktarlarını belirlemek için PDA ve RID dedektörlü HPLC'ye (Shimadzu Prominence-i LC-2030C) enjekte edilmiştir. Analizlerde taşıyıcı faz olarak 0,5 mL/dak akış hızında H_2SO_4 (5 mM) taşıyıcı faz olarak ve formik asit çözeltisi (%0,1) kullanılırken, şeker profili için BIORAD Aminex HPX-87H (300 × 7,8 mm, Bio-Rad; Hercules, CA, ABD) kolon olarak kullanılmıştır (Flores, Hellín ve Fenoll, 2012). Bileşiklerin miktarlarını belirlemek için her bir standart madde için beş farklı konsantrasyonda hazırlanmış ve bileşikler kalibrasyon eğrilerinden ölçülmüştür.

5. İstatistiksel analiz

Bu çalışmada, istatistiksel veri analizi XLStat deneme yazılımı (Addinsoft) kullanılarak gerçekleştirilmiştir. Verilerin içerik seviyelerindeki farklılıklar Duncan testi ile hesaplanmıştır. *P*-değerleri 0.05'ten küçük olan ortalamalar istatistiksel olarak anlamlı kabul edilmiştir.

Bulgular ve Tartışma

1. Antioksidan aktivite (AA) ve Toplam Fenolik madde miktarı (TPC)

Antioksidanlar, reaktif oksijen türlerinin (ROS) neden olduğu hücresel hasarı önleyen veya azaltan bileşiklerdir. *T. indica* infüzyonlarında ölçülen başlıca antioksidan bileşikler; fenolik bileşikler, flavonoidler ve bazı organik asitlerdir. Tablo 1'de, *T. indica* (demirhindi) meyves infüzyonlarının 3, 6 ve 12 dakikalık sürelerle hazırlanması sonucunda oluşan antioksidan aktivite (AA) ve toplam Fenolik madde miktarlarındaki (TPC) değişimleri verilmiştir.

Tablo 1. *T. indica* infüzyonlarının biyokimyasal kompozisyonu

***T. indica* infüzyonları**			
Süre	***3 dakika***	***6 dakika***	***12 dakika***
AntioksidanAktivite			
DPPH (µmol Trolox/L)	2592,38±38,79^{a}	2872,38±48,68^{b}	6780,95±78,68^{c}
ABTS (µmol Trolox/L)	2978,67±19,22^{a}	3432,00±43,41^{b}	7431,33±68,71^{c}
TFM (mg GAE/L)	1777,37±4,24^{a}	2131,36±121,01^{b}	2832,02±6,39^{c}
Şeker Profili			
Sakkaroz (mg/L)	20,33±0,00^{c}	1,13±0,0^{a}	1,41±0,0^{b}
Glikoz (mg/L)	21,45±0,00^{a}	26,18±1,2^{b}	30,47±0,0^{c}
Fruktox (mg/L)	11,88±0,00^{a}	14,30±0,4^{b}	16,90±0,0^{c}
Toplam şeker(mg/L)	*34,35±0,00^{a}*	*41,61±1,6^{b}*	*48,78±0,1^{c}*
Organik Asit Profili			
Sitrik Asit (mg/L)	1,07±0,00^{a}	1,30±0,02^{b}	1,55±0,06^{c}
Tartarik Asit (mg/L)	36,11±0,09^{a}	43,24±0,15^{b}	51,82±0,23^{c}
Malik Asit(mg/L)	4,86±0,00^{a}	6,03±0,04^{b}	7,24±0,06^{c}
Toplam organik asit (mg/L)	*42,03±0,09^{a}*	*50,56±0,21^{b}*	*60,61±0,34^{c}*

± standard deviation

a-c: Aynı satırdaki farklı harfler istatistiksel farklılıkları göstermektedir ($p<0,05$).

3 dakikalık infüzyonda 2592,38 µmol Trolox/L olan DPPH radikal süpürme kapasitesi, 6. dakikada hafif artış göstererek 2872,38 µmol Trolox/L'ye yükselmiş, ancak 12. dakikada 6780,95 µmol Trolox/L ile belirgin şekilde artmıştır ($p<0,05$). Bu durum, infüzyon süresi uzadıkça fenolik bileşiklerin suya daha fazla ekstrakte olduğunu göstermektedir. Literatürde, *T. indica* özlerinin DPPH serbest radikali üzerinde önemli antioksidan etki gösterdiği bildirilmiştir (Sudjaroen et al., 2005). Benzer şekilde, infüzyon süresi arttıkça antioksidan aktivite artışı *Hibiscus sabdariffa* (karkade) gibi bitkilerde de gözlemlenmiştir (Tsai ve ark., 2002).

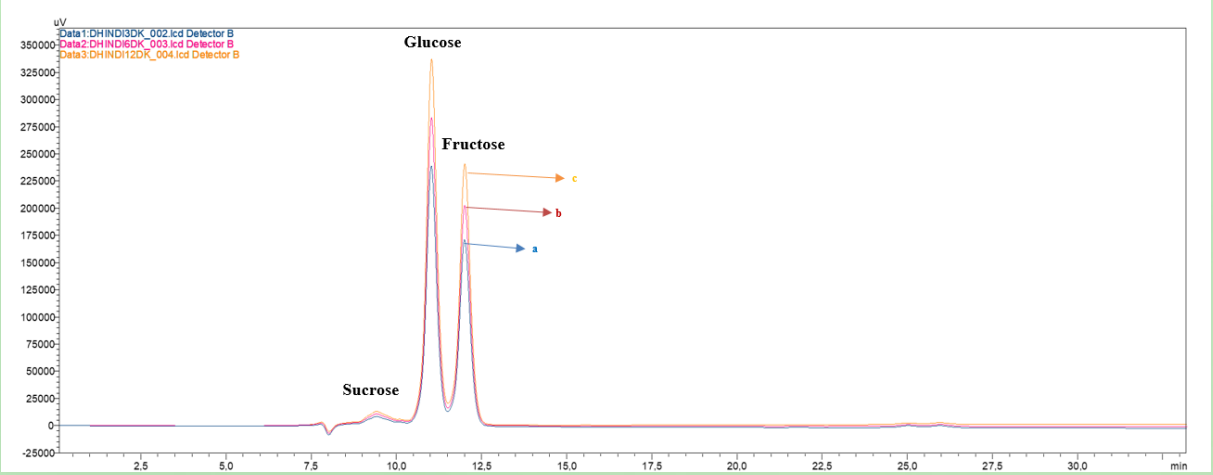
ABTS yöntemi ile belirlenen radikal süpürme kapasitesi ise 3 dakikada 2978,67 µmol Trolox/L iken 6 dakikada 3432,00 µmol Trolox/L ve 12 dakikada 7431,33 µmol Trolox/L'ye yükselmiştir ($p<0,05$). Bu sonuç, ABTS analizinin daha polar fenolik bileşikleri ölçmede etkili olduğunu ve infüzyon süresinin bu bileşiklerin çözünürlüğünü artırdığını göstermektedir (Re ve ark., 1999). Yüksek ABTS ve DPPH aktiviteleri, demirhindi infüzyonunun inflamasyonu azaltıcı ve yaşlanma karşıtı etkiler potansiyeli taşıdığını göstermektedir.

Toplam fenolik madde (TPC) miktarı incelendiğinde ise 3 dakikada 1777,37 mg GAE/L olan TPC, 6. dakikada 2131,36mg GAE/L'ye, 12. dakikada ise 2832,02 mg GAE/L'ye yükselmiştir ($p<0,05$). Fenolik bileşikler suda çözünürlük özelliği taşıdığından, uzun süreli infüzyonlar ekstraksiyon verimliliğini artırmaktadır (Duenas ve ark., 2005). Yüksek TPC değeri, DPPH ve ABTS sonuçları ile paralellik göstermektedir. Fenolik bileşikler serbest

radikalleri etkisiz hale getirerek DNA, lipitler ve proteinlerin oksidatif hasara uğramasını önlemektedir (Scalbert ve ark., 2005). Kronik hastalıkların (kanser, kardiyovasküler hastalıklar, diyabet, Alzheimer) gelişimini azaltıcı etkileri ise bilimsel olarak gösterilmiştir (Manach ve ark., 2004). *T. indica* meyvesi, gallik asit ve ferulik asit gibi güçlü antioksidan fenoller içermektedir (Sudjaroen ve ark., 2005).

2. Şeker profili

T. indica infüzyonlarında doğal olarak bulunan şekerler sakkaroz, glikoz ve fruktoz, enerji sağlamada temel rol oynasa da, sağlık üzerine etkileri tüketim düzeyine göre değişiklik göstermektedir. Tablo 1'de, *T. indica* (demirhindi) meyves infüzyonlarının 3, 6 ve 12 dakikalık sürelerle hazırlanması sonucunda şeker profilinde meydana gelen değişimler, Şekil 1'de ise HPLC-RID ile belirlenen şeker kromatogramı verilmiştir. Sakkaroz miktarı 3 dakikada 20,33 mg/L iken 6 ve 12 dakikada sırasıyla 1,13 ve 1,41 mg/L olarak önemli ölçüde azalmıştır. Bu azalma, sakkarozun parçalanarak glikoz ve fruktoza dönüşmesi ile açıklanabilir. Glikoz miktarı ise 3 dakikada 21,45 mg/L, 6 dakikada 26,18 mg/L ve 12 dakikada 30,47 mg/L'ye çıkmıştır. Fruktoz değeri de benzer bir artış göstermiştir. Toplam şeker içeriği ise 3 dakikada 34,35 mg/L, 6 dakikada 41,61 mg/L ve 12 dakikada 48,78 mg/L olarak artış göstermiştir. ($p<0,05$). Bu sonuçlar, invertaz enzim aktivitesinin etkisini düşündürmektedir. Demirhindi meyvesinde bulunan doğal enzimlerin, sakkarozu parçalayarak glikoz ve fruktoz üretmesi mümkündür. Bu dönüşüm, infüzyon sırasında sıcaklığın etkisiyle hücre duvarlarının geçirgenliği artmakta ve çözünür şekerler kolaylıkla ortama geçmesi ile açıklanmaktadır (Morton, 1987). Aynı zamanda bu dönüşüm hızlı enerji kaynağı sağlarken infüzyonun tatlılık seviyesini artırmaktadır. Glikoz ve fruktoz hızla emilerek kan şekeri seviyesini yükseltmektedir ve aşırı fruktoz tüketimi karaciğer yağlanması ve insülin direnci ile ilişkilendirilmektedir (Tappy ve Lê, 2010). Ancak doğal meyve kaynaklı fruktoz, lif ve fenoliklerle birlikte tüketildiğinde zararlı etkisi azalmaktadır. Mahmood ve ark. (2014,) *T. indica* meyvesinin düşük kalorili içeceklerde doğal tatlandırıcı olarak kullanılabileceği bildirmiştir.



Şekil 1. HPLC-RID ile belirlenen şeker kromatogramı (a: 3 dakikalık infüzyon süresi ile hazırlanan ekstrakt, b: 6 dakikalık infüzyon süresi ile hazırlanan ekstrakt ve c: 12 dakikalık infüzyon süresi ile hazırlanan ekstrakt)

3. Organik asit profili

Organik asitler, sadece tat profiline katkı sağlamakla kalmaz, aynı zamanda sağlık üzerinde çeşitli etkiler göstermektedir. *T. indica* meyve infüzyonlarının 3, 6 ve 12 dakikalık sürelerle hazırlanması sonucunda organik asit profilinde meydana gelen değişimler Tablo 1'de verilmiştir. *T. indica* infüzyonlarında belirlenen başlıca organik asitler arasında sitrik asit, tartarik asit ve malik asit yer almakta olup, bu bileşiklerin toplam konsantrasyonları infüzyon süresi arttıkça anlamlı biçimde yükselmiştir ($p<0,05$). Bu artış, sıcaklığın ve ekstraksiyon süresinin, meyve matrisindeki organik asitlerin çözünürlüğü ve salınımı üzerindeki etkilerini yansıtmaktadır. İnfüzyonun 3. dakikasında toplam organik asit içeriği 42,03 mg/L iken, bu değer 6. dakikada 50,56 mg/L'ye, 12. dakikada ise 60,61 mg/L'ye ulaşmıştır. Özellikle tartarik asit, 36,11 mg/L'den 51,82 mg/L'ye kadar artarak en baskın asit bileşeni olduğunu ortaya koymaktadır. Bu durum, *T. indica* meyvesinin doğal olarak zengin olduğu tartarik asidin, sıcak su infüzyonları yoluyla etkili bir şekilde ekstrakte edilebildiğini göstermektedir. Benzer şekilde, malik asit miktarı da infüzyon süresiyle birlikte artış göstermiş (4,86 mg/L → 7,24 mg/L), bu da malik asidin sıcaklığa duyarlı fakat çözünürlüğü yüksek bir organik asit olduğunu işaret etmektedir. Sitrik asit ise en düşük konsantrasyon düzeyine sahip olmasına rağmen zamanla anlamlı bir artış göstermiştir (1,07 mg/L → 1,55 mg/L). Bu artış, sitrik asidin bitkisel dokulardan geç difüze olması ve daha uzun süreli ekstraksiyon süreçlerinde açığa çıkmasıyla açıklanabilir. Literatürdeki benzer çalışmalar da infüzyon süresinin organik asitlerin ekstraksiyon verimliliği üzerinde belirleyici olduğunu göstermektedir (Mahmood ve ark., 2014; Tsai ve ark., 2002). Bu bağlamda, *T. indica* infüzyonlarının işlenme parametreleri (özellikle süre ve sıcaklık), ürünün

organoleptik özelliklerinin yanı sıra fonksiyonel içeriğini de doğrudan etkilemektedir. Organik asitlerdeki bu artışlar, yalnızca tat profiline katkı sağlamakla kalmayıp, aynı zamanda sindirim fonksiyonları, mineral biyoyararlanımı ve mikrobiyal stabilite açısından da önemli sağlık katkıları sunmaktadır.

Tartışma

Bu çalışma, *T. indica* meyvesinden hazırlanan infüzyonların farklı sürelerde ekstraksiyonu sonucunda meydana gelen biyokimyasal değişimleri kapsamlı bir şekilde ortaya koymuştur. Elde edilen bulgular, infüzyon süresi ile toplam antioksidan kapasite, toplam fenolik madde içeriği, organik asit profili ve şeker düzeyleri arasında anlamlı korelasyonlar olduğunu göstermektedir. Antioksidan aktivitenin, özellikle 12 dakikalık infüzyon süresinde maksimum seviyeye ulaştığı belirlenmiş; bu durum, fenolik bileşikler ve flavonoidlerin sıcaklıkla çözünürlüğündeki artışla ilişkilendirilmiştir. Organik asit profili açısından en belirgin artış tartarik asitte gözlenmiş; malik ve sitrik asit düzeyleri de infüzyon süresine paralel olarak artmıştır. Bu bulgular, *T. indica*'nın karakteristik ekşi tadını belirleyen asidik bileşenlerin sıcak suda çözünürlüğünün süreye bağlı olarak arttığını göstermektedir. Organik asitlerin bu yoğunluğu yalnızca duyusal kaliteyi artırmakla kalmamakta, aynı zamanda sindirimi destekleyici ve mikrobiyal kontrol sağlayıcı etkiler açısından da önem arz etmektedir.

Şeker profili açısından değerlendirildiğinde, özellikle glukoz ve fruktoz düzeylerinin infüzyon süresine bağlı olarak arttığı belirlenmiştir. Bu durum, sıcaklığın meyve dokularının parçalanmasını teşvik etmesi sonucu serbest şekerlerin çözünebilir hale gelmesiyle açıklanabilir. Bununla birlikte, şekerlerin biyoerişilebilirliğini artıran bu durumun, fonksiyonel içecek formülasyonlarında dikkatle değerlendirilmesi gerektiği vurgulanmalıdır.

Genel olarak bu çalışma, *T. indica* infüzyonlarının biyolojik açıdan aktif bileşenlerinin maksimum ekstraksiyonu için infüzyon süresinin kritik bir parametre olduğunu ortaya koymaktadır. Elde edilen veriler, fonksiyonel içeceklerin geliştirilmesinde *T. indica*'nın potansiyel bir doğal antioksidan ve sağlık destekleyici bileşen kaynağı olarak değerlendirilebileceğini göstermektedir. Bu bağlamda, infüzyon süresinin optimize edilmesi, hem besin bileşenlerinin korunumu hem de fonksiyonel etkilerin maksimize edilmesi açısından büyük önem taşımaktadır.

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