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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.

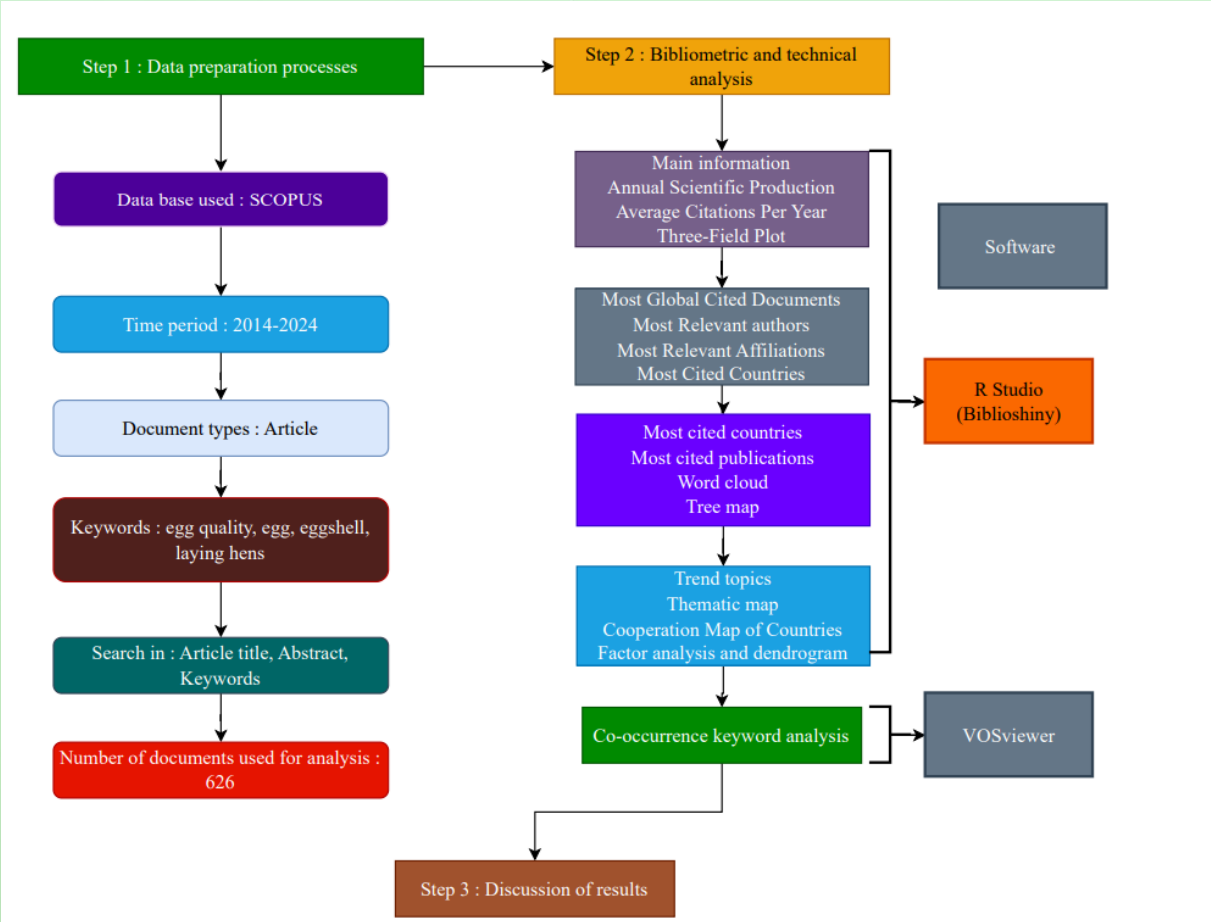

Figure 1. Diagram of the analytical process adopted

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

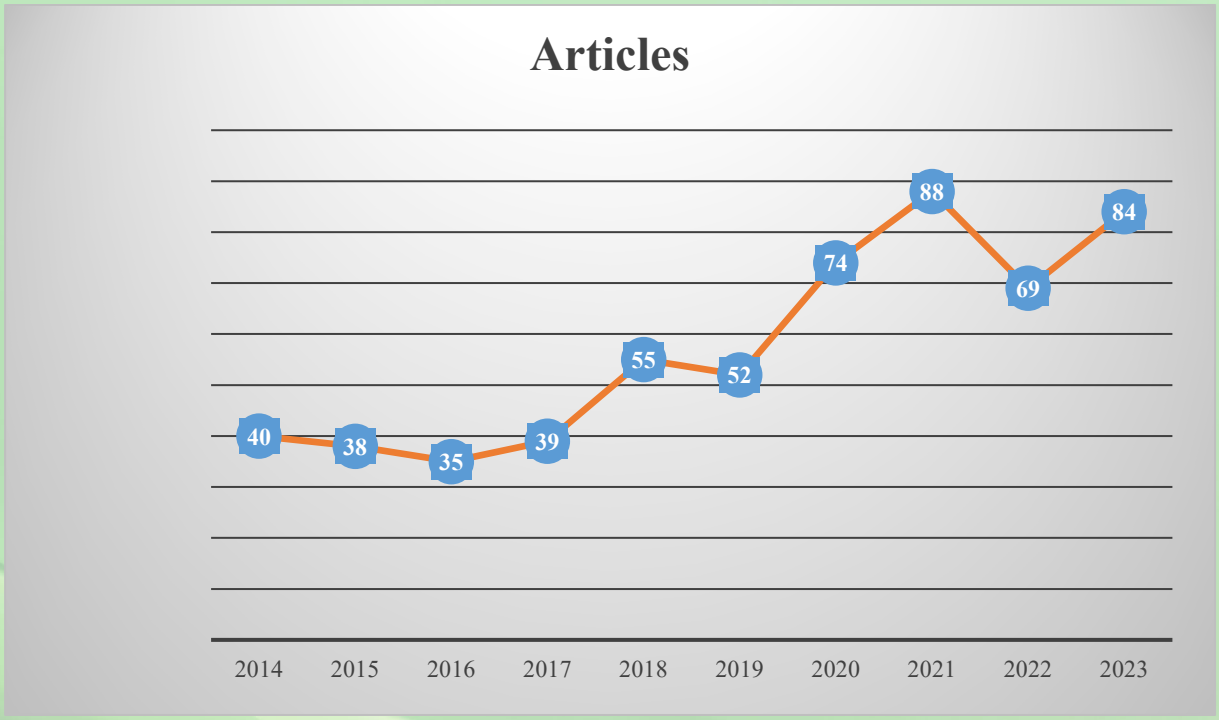

Figure 3: Annual status

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”.

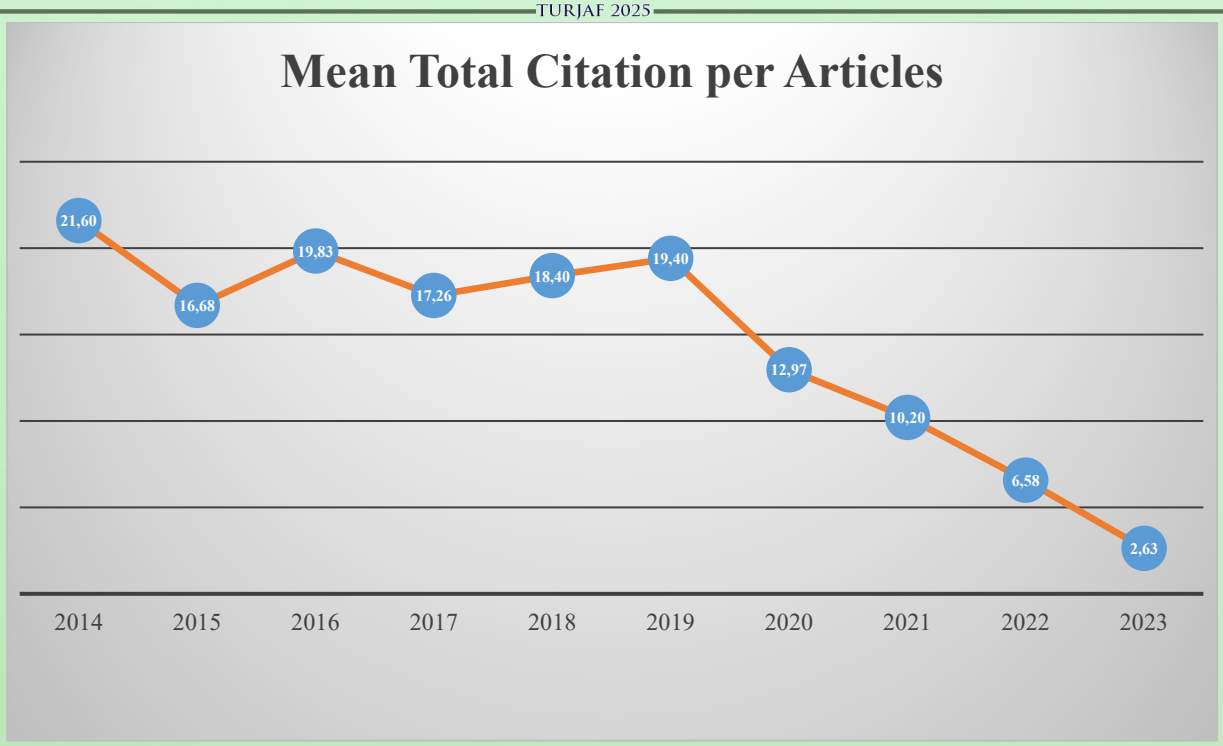

Figure 4. Annual status of citations

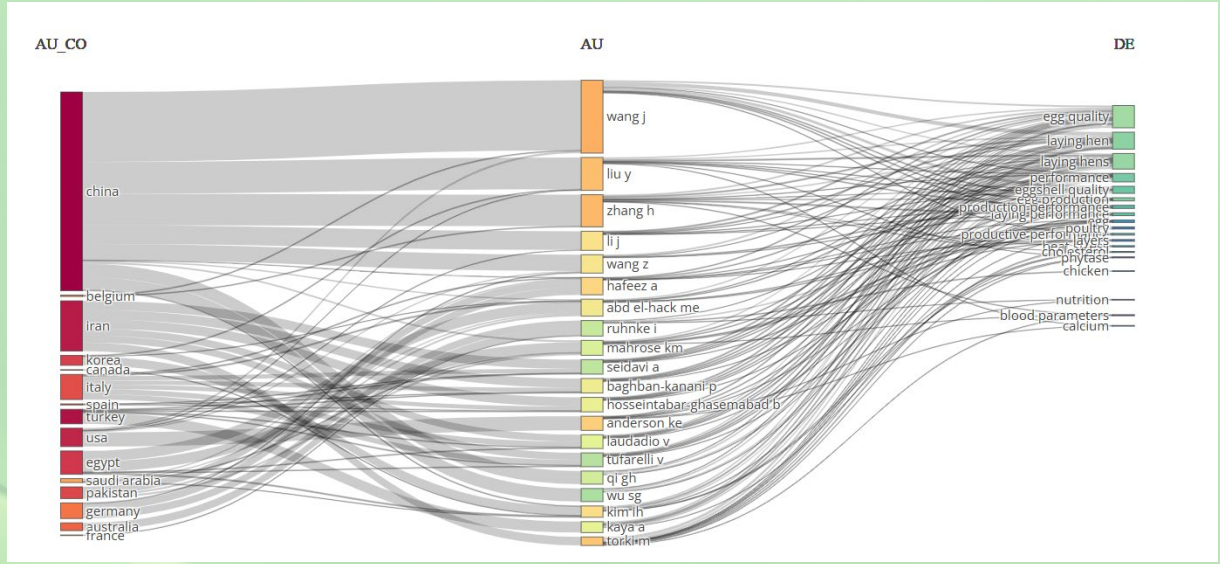

Figure 5. Three field diagrams

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

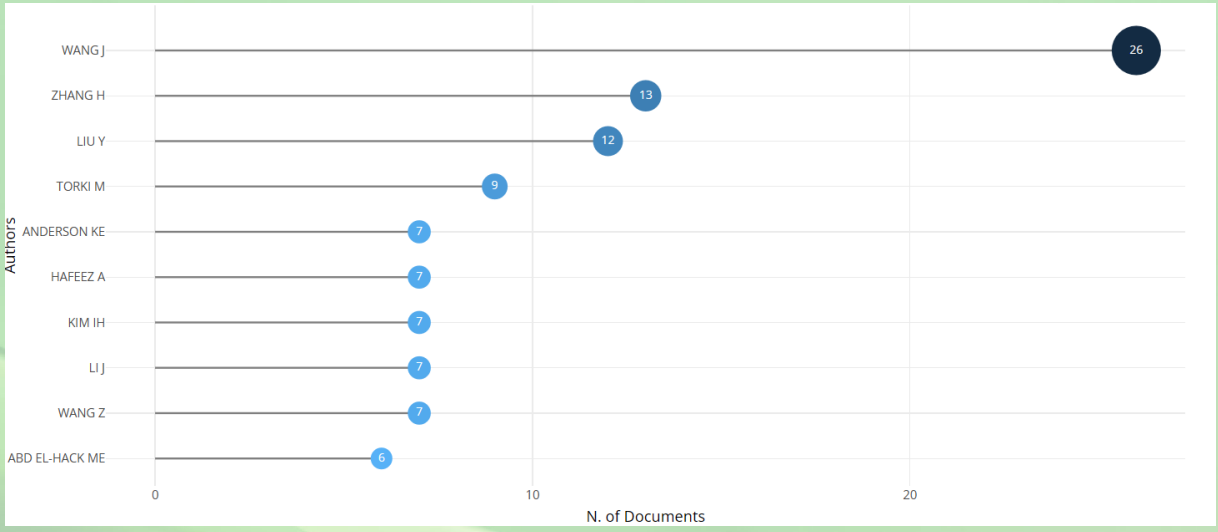

Figure 6. Most prolific authors

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.

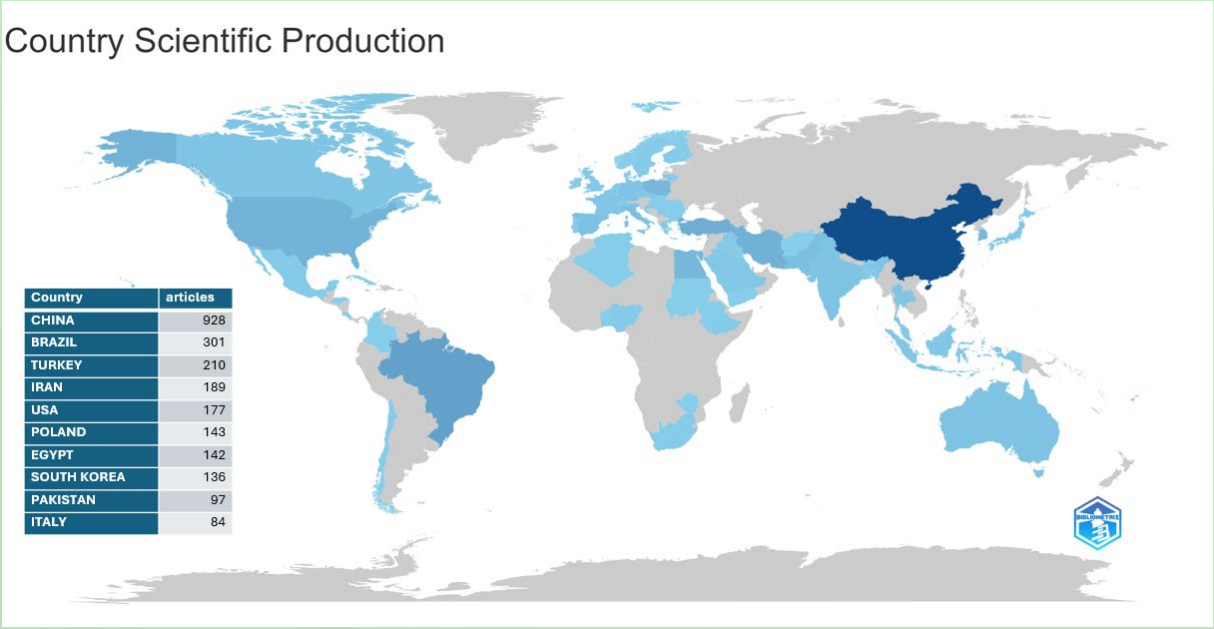

Figure 7. Most productive countries

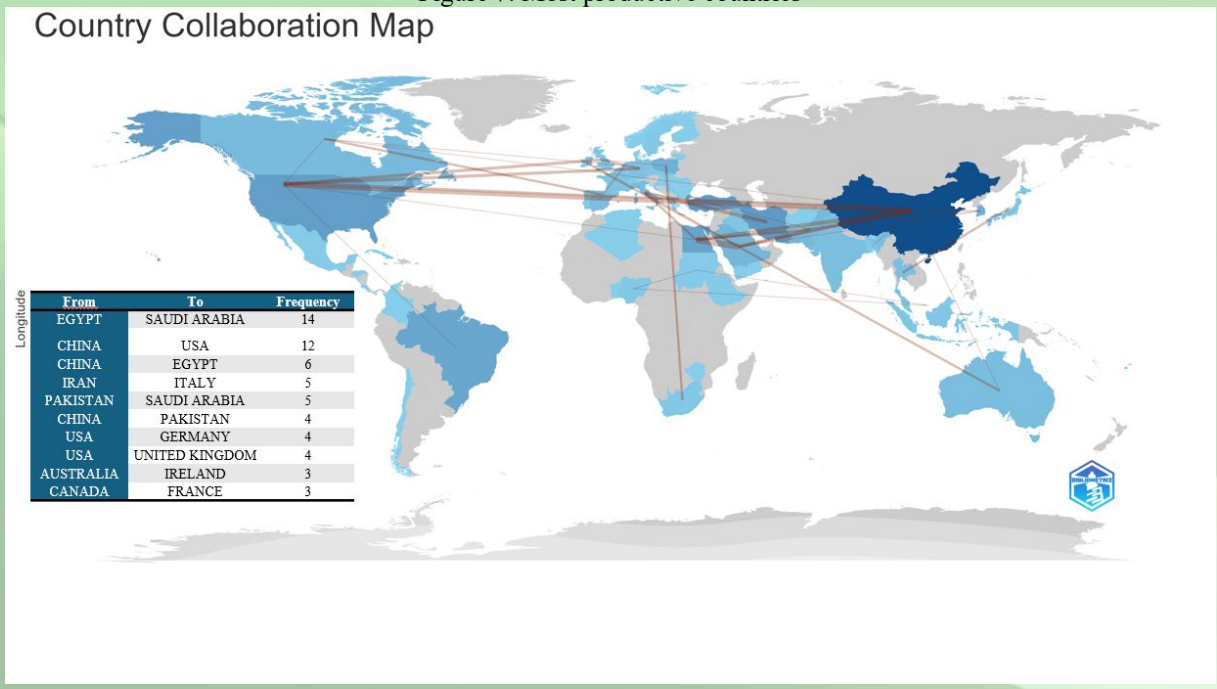

Figure 8. Cooperation map of countries

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

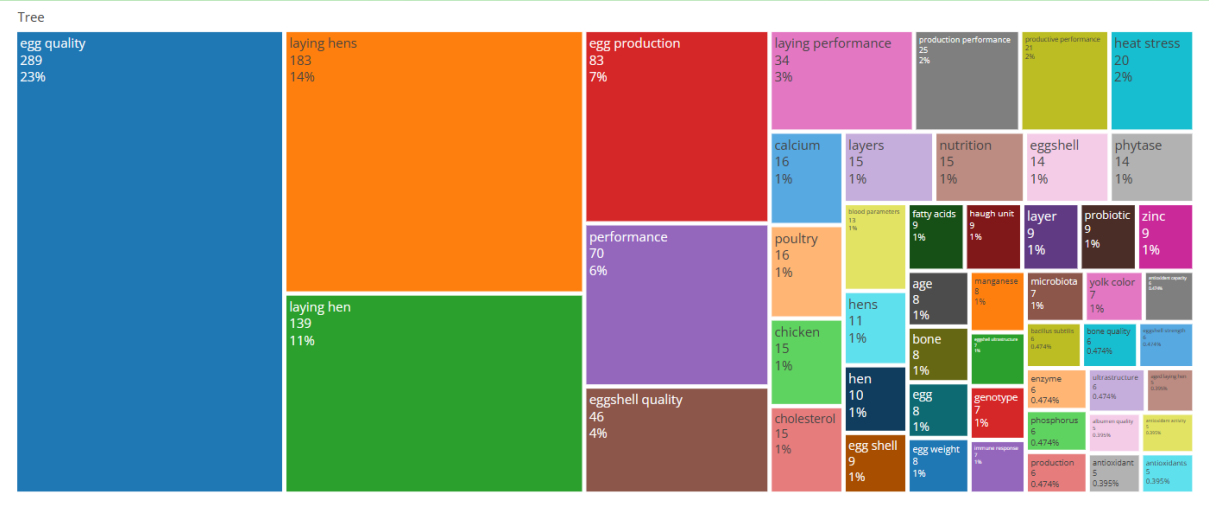

Figure 10. Tree map

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

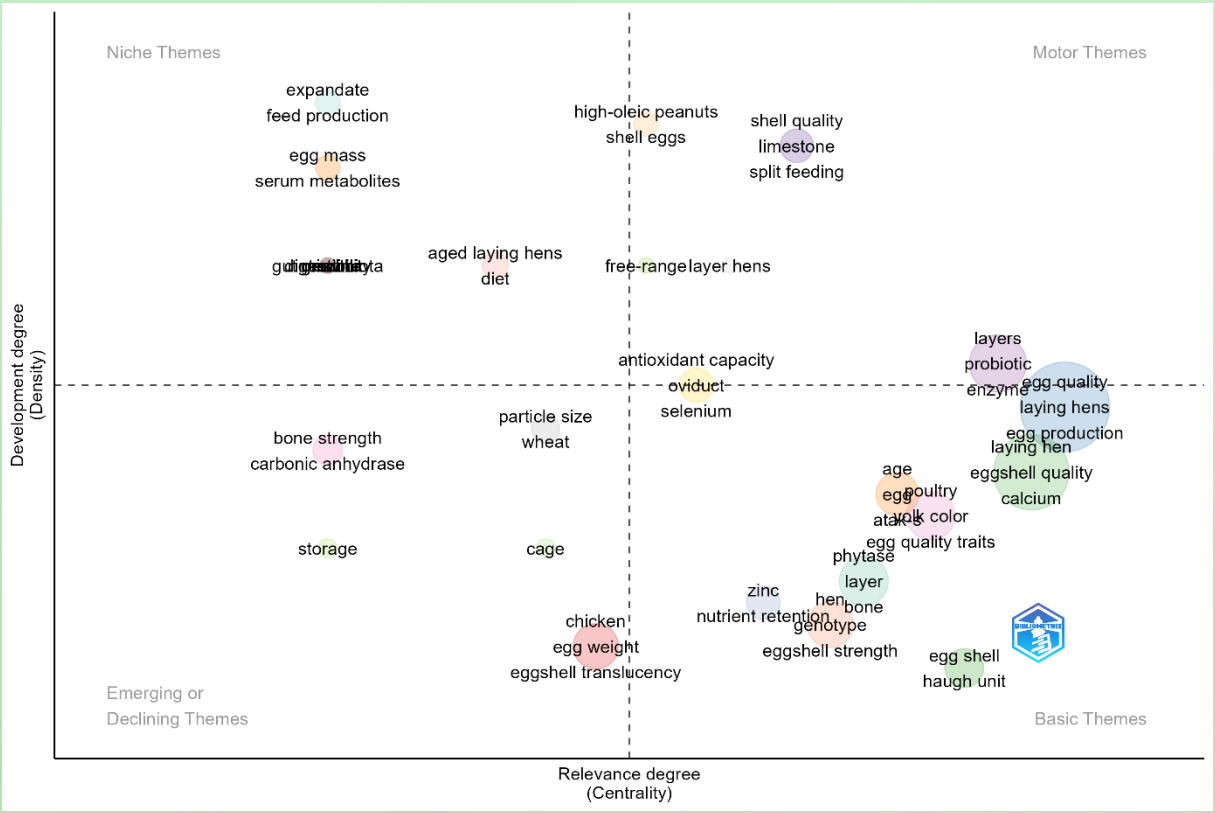

Figure 11. Thematic map

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.

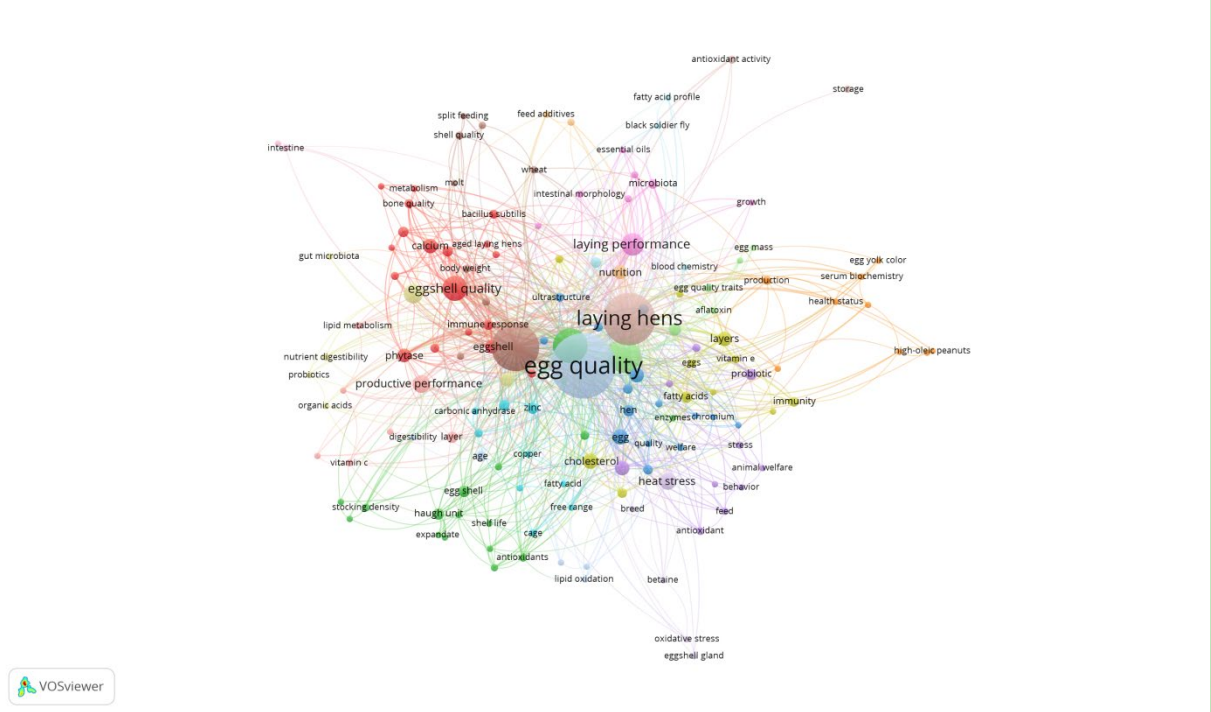

Figure 12. Keyword network map

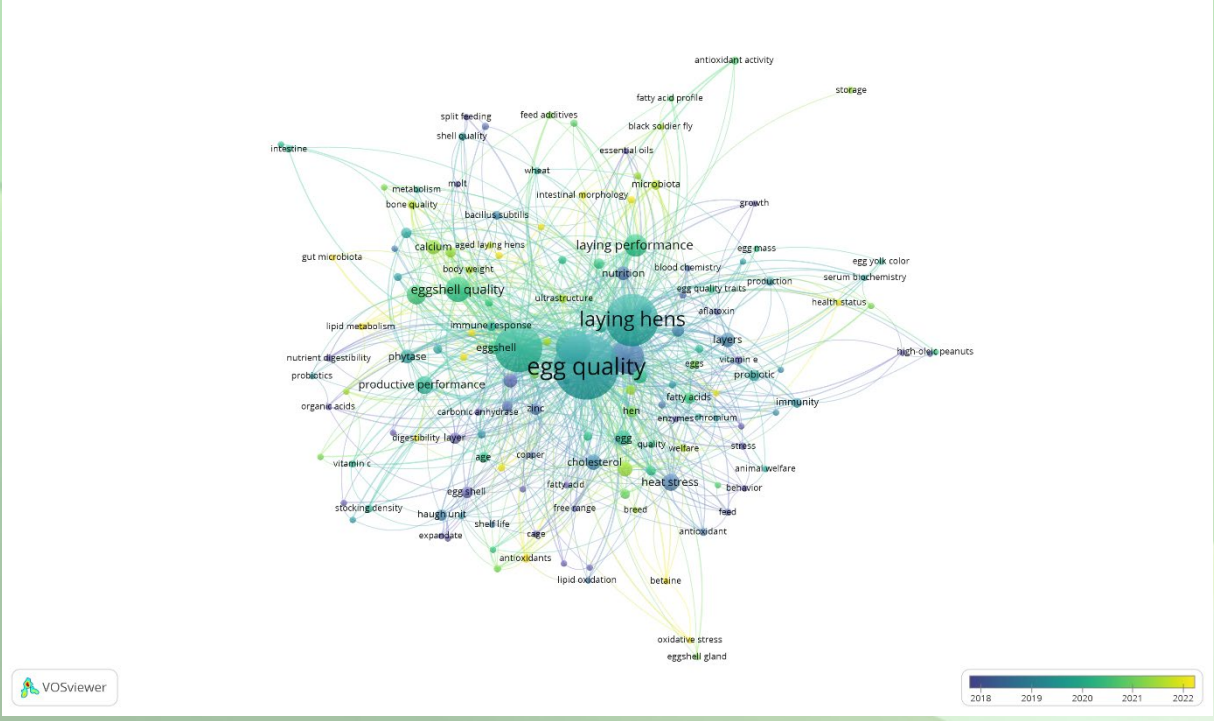

Figure 13. Timeline of keywords

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.

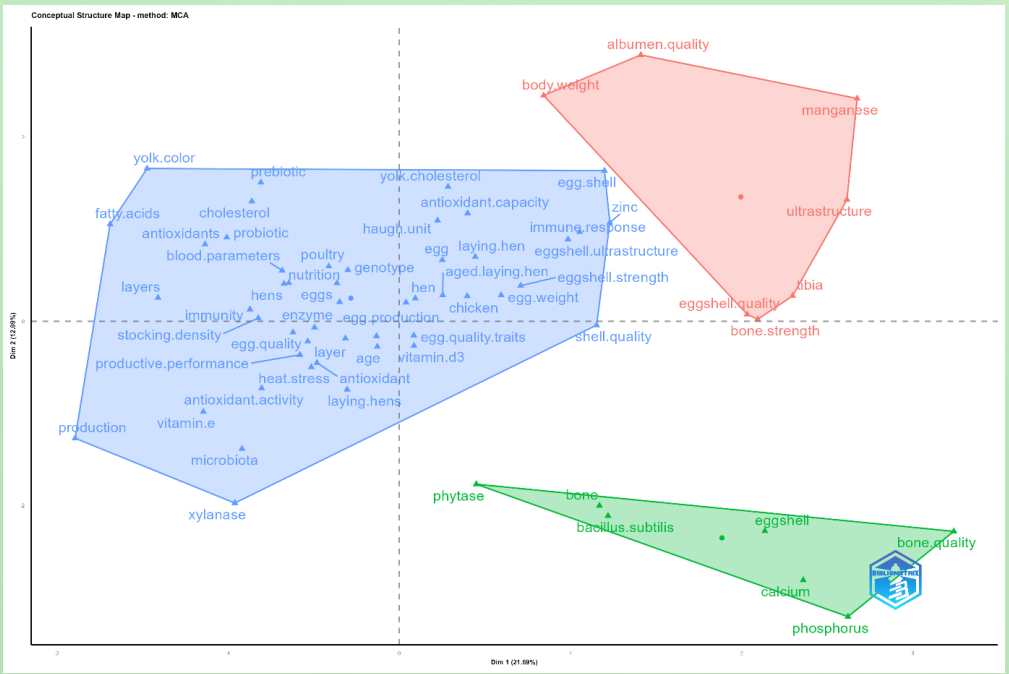

Figure 14. Factor analysis of author-keywords

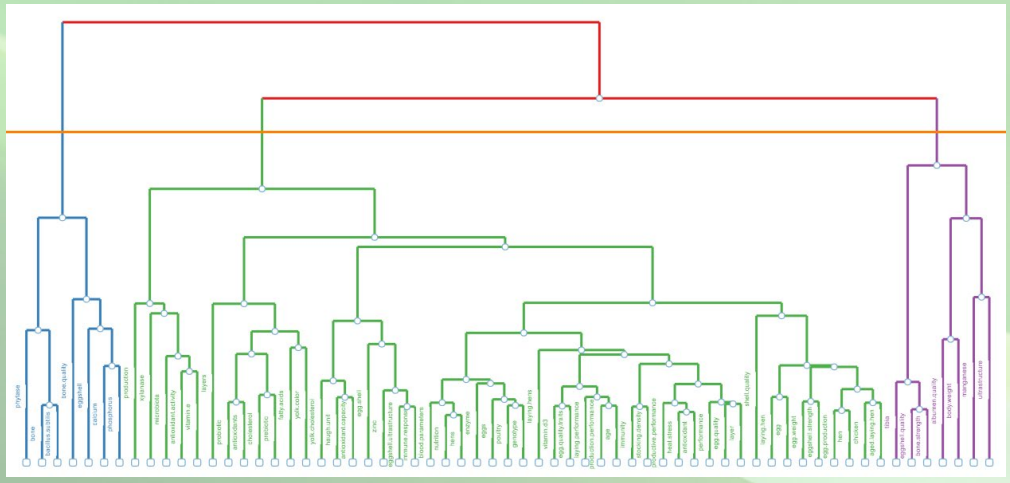

Figure 15. Topic dendrogram of author keywords

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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