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Valorization of Stale Bread in Tunisian Traditional Cookies: A Sustainable Approach to Maachech Formulation

Borhen Dahmen

Food industry engineering, Tunisia

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 sensorially 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 $28.39 \pm 0.23\%$, 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 ($\Delta E \approx 2.3$) 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

