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Editorial

Functional Bakery Products: Technological, Chemical and Nutritional Modification

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Increasing consumer interest in the health benefits of various foods has driven the development of new food products and prompted modifications to the recipes and technologies used for the production of traditional items. Nutritional claims such as "source of…", "rich in…", and "light" have become increasingly common, reflecting a stronger focus on health benefits [1,2]. Current research trends emphasize the nutritional and technological advancements reflected in cereal-based products, including the incorporation of novel additives and production processes aimed at achieving clean-label recognition [3,4]. Functional foods provide a valuable platform for introducing new ingredients, offering benefits from economic, nutritional, technological, and environmental perspectives. This approach not only enhances nutritional value but also addresses dietary deficiencies in the population. Moreover, in response to the global challenge of food waste, extensive research has been conducted to explore the potential for utilizing by-products from the food industry—such as those from fruit, vegetable, or oil processing—as well as underutilized mill streams rich in fiber fractions. Developing technological solutions to integrate these by-products into higher-quality products will lead to an enhancement in their economic value, improve resource efficiency, and support zero-waste principles, advancing a circular economy [5–7].

These trends also extend to bakery products, which are typically made from flour or meal derived from a variety of both cereal and non-cereal grains. Depending on the ingredients present, bakery products can serve as excellent sources of complex carbohydrates (including starch and dietary fiber), proteins, vitamins, minerals, and phytochemicals with specific health benefits. Bakery items such as bread, cookies, cereal bars, biscuits, and muffins play a central role in the modern diet, representing numerous opportunities to enhance their nutritional value, functionality, and alignment with current health and sustainability values [8–11].

One common strategy with which to enhance the nutritional value of bakery products is the partial or complete substitution of wheat flour. This approach is particularly effective for products in which wheat flour is a primary ingredient, such as refined (low-extraction) wheat bread. Refined flour, depending on its extraction rate, is characterized by low levels of dietary fiber, protein, minerals, and bioactive compounds. Additionally, the proteins in wheat flour are incomplete, lacking certain essential amino acids, particularly lysine, limiting their digestibility [12–15]. Bread, one of the most widely consumed bakery products, has an average per capita consumption of around 250 g per day [16] and plays a vital role in human nutrition due to its accessibility and nutritional value. Wheat bread, the most common type of bread, has been a dietary staple for centuries. It provides a substantial energy source through its high carbohydrate content (70–80% dry matter) and also supplies protein (10–14% dry matter) and minerals (0.5–0.8% dry matter). However, the dietary fiber content in white wheat bread is relatively low, typically at around 2–3% [17]. To address

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these nutritional limitations, there is a rising trend of incorporating non-traditional raw materials, including high-protein by-products from the plant food industry, into bread and other bakery products traditionally made using white wheat flour [18].

While partially substituting wheat flour with another ingredient can improve the chemical composition of baked goods, this method also poses significant challenges, particularly in maintaining the quality characteristics of the final product, which are critical for consumer acceptance. Wheat flour is unique because of its gluten content, a structural protein essential for the appearance, crumb structure, and overall texture of many baked goods. The gluten matrix plays a crucial role in determining the rheological properties of dough, making it challenging to replace wheat flour without compromising product quality. Enriching raw materials often need to be used in limited amounts, as excessive additions can negatively impact the dough quality, microstructure, and texture of the final product [19]. Developing dough with desirable properties becomes even more challenging when formulating gluten-free bakery products. This issue is particularly significant considering the rising global incidence of celiac disease, which has reached annual rates of 21.3 cases per 100,000 individuals among children and 12.9 per 100,000 individuals among adults in recent years [20]. Patients with celiac disease often face limited access to suitable products, which are frequently characterized by lower nutritional and sensory quality compared with their gluten-containing counterparts. This presents specific challenges, not only in achieving the desired dough quality but also in ensuring that the final product meets appropriate nutritional standards [21].

Recent studies in the field of functional bakery products have increasingly focused on incorporating unconventional ingredients and innovative technologies to enhance the nutritional, sensory, and technological properties of baked goods. Examples include the use of industrial by-products, such as fruit pomace, vegetable processing waste, and underutilized mill streams rich in fiber fractions, as well as ingredient modifications like inulin, microalgae, or mushroom powders. Additionally, enriching products with gluten-free or clean-label alternatives as a strategy has gained attention. Such strategies aim not only to improve the health benefits of bakery products but also to align with sustainability trends by minimizing waste and promoting eco-friendly practices in the food industry.

One promising area of research explores the application of enzymatic, thermal, hydrothermal, and enzyme-assisted hybrid modifications in underutilized mill streams [22]. These modifications aim to incorporate wheat flour fractions, which account for about 10% of milling production, into bread-making while maintaining desirable properties. Thermal treatments, especially when combined with enzymes, were found to enhance bread yield and water absorption without compromising texture or color. The treatments reduced amylase activity and starch retrogradation, improved bread volume (up to 16%), and lowered baking and weight losses by 8% compared to standard wheat bread. However, hydrothermal treatments negatively impacted dough structure and crust formation despite increasing bread volume and yield. Flour blends containing up to 20% of modified fractions proved effective as clean-label bread improvers, though higher levels reduced product quality. These findings have practical applications for milling companies, enabling them to reduce waste and create ready-to-use bakery blends with clean-label benefits. Future research should aim to optimize production processes and explore additional enzymes and flour types to further enhance bread quality.

Another innovative study examined the fortification of cereal bars with grape and apple pomace, by-products of the fruit industry, to enhance their nutritional value, physical properties, and sensory characteristics [23]. Replacing 10 or 20 g of sultanas with these pomaces increased the bars' moisture and soluble dietary fiber content while reducing their antioxidant levels. Fortification improved their mechanical strength and visual appeal, though noticeable color changes and less acceptable aroma and texture were also observed in some cases. Cereal bars fortified with grape pomace and up to 10 g of apple pomace demonstrated high dietary fiber content, desirable sensory properties, and suitability for industrial production. However, bars containing 20 g of apple pomace exhibited excessive

moisture and lower mechanical integrity, raising concerns about storage stability and transportation. Future studies should evaluate the shelf life and stability of fortified bars and explore methods to minimize color changes during storage.

The impact of inulin (5–40%) on the rheological, textural, and sensory properties of rice bread was also explored to assess its potential for enhancing gluten-free bakery products [24]. Inulin addition softened the dough, raised the gelatinization temperature, and improved bread characteristics, including the specific loaf volume (1.16–1.48 mL/g), crumb porosity (36–58%), and sensory appeal. The optimal inulin level was found to be 30%; this produced bread with superior texture, porosity, and sensory properties, while aligning with dietary recommendations by providing approximately 23 g of inulin per serving. However, higher inulin levels (40%) led to a deterioration in bread texture and cohesiveness, along with increased baking losses. These findings highlight the potential to use inulin in gluten-free bread production and suggest that further research on its application in other bakery products, such as pastries, be conducted.

Functional bakery products provide an excellent platform for enhancing human health and promoting sustainability through ingredient modifications and innovative processing techniques. The reviewed studies highlight the potential of utilizing industrial by-products and functional ingredients, such as inulin, to improve the nutritional, sensory, and technological properties of bakery products while simultaneously addressing waste reduction and sustainability objectives. Future research should focus on developing scalable production methods for the incorporation of modified flours and by-products into bakery formulations without compromising product quality, assessing the long-term stability and shelf life of fortified products, investigating consumer preferences, especially for products with noticeable changes in sensory characteristics such as color, texture, or aroma, and evaluating the bioavailability of nutrients in functional products and their potential health benefits. With continued advancements in ingredient utilization and processing technologies, functional bakery products have the potential to make a significant contribution to health, sustainability, and waste reduction in the food industry.

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References

1. Verhagen, H.; Vos, E.; Francl, S.; Heinonen, M.; Van Loveren, H. Status of Nutrition and Health Claims in Europe. *Arch. Biochem. Biophys.* **2010**, *501*, 6–15. [CrossRef] [PubMed]
2. Duarte, P.; Teixeira, M.; Costa, E.; Silva, S. Healthy Eating as a Trend: Consumers' Perceptions towards Products with Nutrition and Health Claims. *Rev. Bras. Gest. Neg.* **2021**, *23*, 405–421. [CrossRef]
3. Cappelli, A.; Bettaccini, L.; Cini, E. The kneading process: A systematic review of the effects on dough rheology and resulting bread characteristics, including improvement strategies. *Trends Food Sci. Technol.* **2020**, *104*, 91–101. [CrossRef]
4. Vargas, M.C.A.; Simsek, S. Clean label in bread. *Foods* **2021**, *10*, 2054. [CrossRef]
5. Jung, J.-M.; Kim, J.Y.; Kim, J.-H.; Kim, S.M.; Jung, S.; Song, H.; Kwon, E.E.; Choi, Y.-E. Zero-waste strategy by means of valorization of bread waste. *J. Clean. Prod.* **2022**, *365*, 132795. [CrossRef]
6. Jimenez-Moreno, N.; Esparza, I.; Bimbela, F.; Gandia, L.M.; Ancin-Azpilicueta, C. Valorization of selected fruit and vegetable wastes as bioactive compounds: Opportunities and challenges. *Crit. Rev. Environ. Sci. Technol.* **2020**, *50*, 2061–2108. [CrossRef]
7. Dymchenko, A.; Geršl, M.; Gregor, T. Trends in bread waste utilisation. *Trends Food Sci. Technol.* **2023**, *132*, 93–102. [CrossRef]
8. Goubgou, M.; Songré-Ouattara, L.T.; Bationo, F.; Lingani-Sawadogo, H.; Traoré, Y.; Savadogo, A. Biscuits: A systematic review and metaanalysis of improving the nutritional quality and health benefits. *Food Prod. Process. Nutr.* **2022**, *3*, 26. [CrossRef]
9. Cacak-Pietrzak, G.; Dziki, D.; Gawlik-Dziki, U.; Sułek, A.; Kalisz, S.; Sujka, K. Effect of the Addition of Dried Dandelion Roots (*Taraxacum officinale* F. H. Wigg.) on Wheat Dough and Bread Properties. *Molecules* **2021**, *26*, 7564. [CrossRef] [PubMed]
10. Bianchi, F.; Cervini, M.; Giuberti, G.; Rocchetti, G.; Lucini, L.; Simonato, B. Distilled grape pomace as a functional ingredient in vegan muffins: Effect on physicochemical, nutritional, rheological and sensory aspects. *Int. J. Food Sci. Technol.* **2022**, *57*, 4847–4858. [CrossRef]
11. Borges, M.S.; Biz, A.P.; Bertolo, A.P.; Bagatini, L.; Riego, E.; Cavalheiro, D. Enriched cereal bars with wine fermentation biomass. *J. Sci. Food Agric.* **2020**, *101*, 542–547. [CrossRef] [PubMed]

12. Villarino, C.B.J.; Jayasena, V.; Coorey, R.; Chakrabarti-Bell, S.; Johnson, S. Nutritional, Health, and Technological Functionality of Lupin Flour Additionto Bread and Other Baked Products: Benefits and Challenges. *Crit. Rev. Food Sci. Nutr.* **2016**, *56*, 835–857. [CrossRef] [PubMed]
13. Shewry, P.R.; Hey, S.J. The contribution of wheat to human diet and health. *Food Energy Secur.* **2015**, *4*, 178–202. [CrossRef] [PubMed]
14. Rawat, M.; Varshney, A.; Rai, M.; Chikara, A.; Pohty, A.L.; Joshi, A.; Binjola, A.; Singh, C.P.; Rawat, K.; Rather, M.A.; et al. A comprehensive review on nutraceutical potential of underutilized cereals and cereal-based products. *J. Agric. Food Res.* **2023**, *12*, 100619. [CrossRef]
15. Sułek, A.; Cacak-Pietrzak, G.; Różewicz, M.; Nieróbca, A.; Grabiński, J.; Studnicki, M.; Sujka, K.; Dziki, D. Effect of Production Technology Intensity on the Grain Yield, Protein Content and Amino Acid Profile in Common and Durum Wheat Grain. *Plants* **2023**, *12*, 364. [CrossRef] [PubMed]
16. Mollakhalili-Meybodi, N.; Ehrampoush, M.H.; Hajimohammadi, B.; Mosaddeg, M.H. Formulation optimization of functional wheat bread with low glycemic index from technological and nutritional perspective. *Food Sci. Nutr.* **2023**, *11*, 284–294. [CrossRef] [PubMed]
17. Almeida, E.L.; Chang, Y.K.; Steel, C.J. Dietary fibre sources in bread: Influence on technological quality. *LWT* **2013**, *50*, 545–553. [CrossRef]
18. Zarzycki, P.; Wirkijowska, A.; Nawrocka, A.; Kozłowicz, K.; Krajewska, M.; Kłosok, K.; Krawęcka, A. Effect of Moldavian dragonhead seed residue on the baking properties of wheat flour and bread quality. *LWT* **2022**, *155*, 112967. [CrossRef]
19. Azadfar, E.; Rad, A.H.; Sharifi, A.; Armin, M. Effect of olive pomace fiber on the baking properties of wheat flour and flat bread (Barbari Bread) quality. *J. Food Process. Preserv.* **2023**, *2023*, 1405758. [CrossRef]
20. Celiac Disease Foundation. Incidence of Celiac Disease Steadily Increasing. 2020. Available online: https://celiac.org/about-the-foundation/featured-news/2020/02/incidence-of-celiac-disease-steadily-increasing/ (accessed on 15 November 2024).
21. See, J.A.; Kaukinen, K.; Makharia, G.K.; Gibson, P.R.; Murray, J.A. Practical insights into gluten-free diets. *Nat. Rev. Gastroenterol. Hepatol.* **2015**, *12*, 580–591. [CrossRef]
22. Lewko, P.; Wójtowicz, A.; Gancarz, M. Application of Conventional and Hybrid Thermal-Enzymatic Modified Wheat Flours as Clean Label Bread Improvers. *Appl. Sci.* **2024**, *14*, 7659. [CrossRef]
23. Blicharz-Kania, A.; Vasiukov, K.; Sagan, A.; Andrejko, D.; Fifowska, W.; Domin, M. Nutritional Value, Physical Properties, and Sensory Quality of Sugar-Free Cereal Bars Fortified with Grape and Apple Pomace. *Appl. Sci.* **2023**, *13*, 10531. [CrossRef]
24. Burešová, I.; Šebestíková, R.; Šebela, J.; Adámková, A.; Zvonková, M.; Skowronková, N.; Mlček, J. The Effect of Inulin Addition on Rice Dough and Bread Characteristics. *Appl. Sci.* **2024**, *14*, 2882. [CrossRef]

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