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Alternative Flours in Baking: A Comprehensive Review of Health Benefits and Application in Baking

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Abstract

The rise in consumer health awareness has driven significant interest in exploring alternative flours beyond traditional wheat. This review examines the functional and nutritional benefits of various alternative flours, including almonds, oats, millet, sorghum, barley, rice, maize, rye, and chickpea, in baking applications. Almond flour offers high protein and healthy fats, beneficial for gluten-free baking but varies in sensory attributes. Oat flour, rich in beta-glucan, enhances heart health and digestion, with sprouted oats improving dough handling and product texture. Millet flour, including pearl millet, boosts fiber content and has a low glycemic index, while sorghum flour provides a viable gluten-free option with good nutritional and sensory qualities. Barley flour adds fiber and phenolic compounds, though it affects color and texture. Rice flour improves the texture of gluten-free cakes, and maize flour can substitute refined flour, though it may alter color and sensory characteristics. Rye flour, known for its high dietary fiber, offers potential health benefits but requires careful handling for optimal bread-making performance. Chickpea flour enhances nutritional value with high protein and bioactive compounds, especially when blended with other flour. The integration of these alternative flours enriches the baking landscape, catering to diverse dietary needs and preferences. Future research should focus on optimizing their sensory and functional properties to maximize their potential in baked goods, contributing to a healthier and more varied food industry.

Keywords: Wheat flour, baking, flour alternatives, flour enhances nutrition, baked products

INTRODUCTION

In the realm of baking, wheat flour, particularly all-purpose flour, has long been the foundation for creating a wide array of baked goods, including cakes, bread, and cookies. Its unique properties, primarily owing to its gluten content, provide the necessary structure and elasticity that contribute to the desirable texture and appearance of these products. However, reliance on wheat flour has its own set of limitations, especially concerning the nutritional profile and dietary restrictions for certain consumers.

The demand for baking products is witnessing an annual growth rate of 10.07%. The food industry is entrusted with the challenge of designing new food items with unique health characteristics [1].

With increasing awareness of health and wellness, there is a growing interest in enhancing the nutritional value of baked products. Incorporating or substituting alternative flour can significantly improve the nutritional content by adding essential vitamins, minerals, fibers, and

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proteins that are often lacking in traditional wheat flour [2]. This shift is particularly important in addressing the needs of individuals with gluten intolerance or celiac disease who require gluten-free options to avoid adverse health effects.

Alternative flours, such as rice flour, millet, rye, barley, maize, oats, and almond flour, offer a range of benefits that go beyond being gluten-free. These flours can contribute to a more diverse and balanced diet, providing various health benefits, such as improved digestion, better glycemic control, and enhanced heart health [3, 4]. For example, oat flour is rich in β-glucan, which is known for its cholesterol-lowering properties, whereas almond flour is high in healthy fats and proteins, making it a great option for low-carbohydrate diets.

The integration of these alternative flours in baking not only caters to dietary needs but also opens up a world of new flavors and textures, enriching the culinary experience [5]. Bakers and food scientists are increasingly exploring these options to innovate and diversify their product offerings, creating baked goods that are not only delicious but also nutritious.

This review presents a comprehensive analysis of various alternative flours, highlighting their potential benefits and applications in baking. By understanding the functional properties and nutritional advantages of these flours, informed decisions can be made to improve the quality and health of baked products, ultimately promoting better dietary practices and catering to a wider range of consumer needs [6, 7].

LITERATURE REVIEW

Almond Flour

Almond flour has a nutty flavor, but it also has a rich, buttery, and sweet taste. Almond flour has gained popularity as a gluten-free substitute for wheat flour and other grain-based flour because it is made from nuts rather than grains [8]. Using almond flour instead of wheat flour or other gluten-free flour has the added benefit of increasing the protein level of recipes while lowering the carbohydrate load.

According to data from the US Department of Agriculture, one ounce of whole almonds or ½ cup of almond flour contains 161 calories, 14 g of fat (and only 1 g of saturated fat), 6 g of carbohydrates, 3 g of fiber, 1 g of sugar, 6 g of protein, 1.7 grams of omega-3 fatty acids, and 3.3 grams of omega-6 fatty acids [9, 10]. Additionally, this amount of almond flour provides 37% of the daily value (DV) of vitamin E, 32% of manganese, 19% of magnesium, 17% of riboflavin, 14% of copper, 14% of phosphorus, 7% of calcium, 6% of iron, 6% of zinc, 5% of niacin, 4% of thiamine, and 3% of folate.

This study explored the production and sensory evaluation of cakes made from a blend of wheat and almond seed flour [11]. Using an experimental design, sensory attributes (color, texture, taste, aroma, mouthfeel, and general acceptability) were assessed by 20 panelists. Sensory data were analyzed using ANOVA and Duncan's Multiple Range Test, with significance set at $p<0.05$.

The results showed that the control sample (100% wheat flour) scored the highest in most sensory attributes, although its aroma score was not significantly higher than that of the other samples. Cakes with a blend of wheat and almond flour had sensory qualities comparable to those of 100% wheat flour cake, while 100% almond seed flour cake scored the lowest across all attributes [12].

The study concluded that combining almond seed flour with wheat flour can produce cakes with good sensory qualities, potentially reducing the reliance on wheat flour alone for cake production. The blend was particularly well received in terms of taste, aroma, and mouthfeel, except for 100% almond seed flour cake, which was the least acceptable.

Oat Flour

Oats (Avena sativa) are cereal grains produced by seeds. Oats are used in a variety of dishes, most notably muesli, which is rolled or crushed and milled into fine flour [13, 14]. Oatmeal is typically consumed as porridge, but it can also be used in a range of baked foods including oatcakes, oatmeal cookies, and oat bread.

Oats contain approximately 60% starch, 14% proteins, 7% lipids, and 4% β-glucans. High β-glucan content is particularly important because of its cholesterol-lowering effect, which has led to the acceptance of oats as a health food. Scientific research has shown that eating oatmeal bread, which is naturally enriched in β-glucan, improves insulin resistance in patients with type II diabetes. Because of their polysaccharide and fiber content, oats have a high satiety capacity, digest slowly, bind water, increase their volume, and accelerate the onset of satiety [15, 16, 17]. Oat fiber serves as a prebiotic, enhancing the composition of the intestinal microbiota, which improves digestion and helps prevent constipation.

Studies have explored the effects of incorporating sprouted oats (SO) and unsprouted oats (USO) into wheat dough, focusing on dough properties and biscuit characteristics. Dough treated with USO showed weakened gluten aggregation, increased water absorption, and decreased extensibility. In contrast, dough with SO had mixing profiles similar to wheat but showed weakened gluten and altered rheological properties, especially at the 20% SO inclusion level. Biscuits made with SO had reduced hardness and toughness, with the most significant effects observed when oats sprouted for 72 h were used [18]. The research suggests that using sprouted oats in baked goods can influence dough handling and texture, and further studies are planned to evaluate consumer acceptability and nutritional quality.

Researchers have examined the use of dry fractionated oat flour (DFOF) as a functional ingredient in bread and evaluated its impact on the functional, nutritional, and structural properties of dough and bread. The DFOF was divided into fractions based on particle size: F1 (<224 µm), F2 (250–280 µm), F3 (280–500 µm), F4 (500–600 µm), and whole oat flour (F5), and blended with white wheat flour at substitution levels of 10%, 30%, and 50%. The analysis revealed that the F3 fraction with 50% substitution had the highest water absorption, while F1 with 50% substitution had the highest peak viscosity. The inclusion of DFOF fractions increased β-glucan levels and decreased fermentable monosaccharides (glucose and fructose) in bread, indicating potential health benefits [19]. However, the particle size of the fractions had a more significant effect on bread volume reduction than the substitution level. Finer fractions at 10% substitution yielded bread with a structure and volume similar to 100% wheat flour bread but with enhanced nutritional value, including improved bread volume, cell number, and springiness.

The study concluded that using a dry mechanical fractionation process to produce DFOF fractions can enhance the functionality and nutritional quality of oat flour in bread-making. The 500–600 µm fraction at a 30% substitution level produced bread that was structurally similar to white wheat bread, but nutritionally superior. This research suggests that further exploration of the sensory properties of these breads is necessary to ensure consumer acceptance.

Millet

Millets are nutrient-rich ancient grains that offer numerous health benefits. They provide essential nutrients such as fiber, minerals, and antioxidants, which aid in digestion, improve bone health, and help prevent diseases. Their low glycemic index makes them suitable for maintaining stable blood sugar levels and for managing diabetes. Additionally, being gluten-free, millet is ideal for individuals with celiac disease and promotes a healthy gut. Incorporating millet into our daily diet can enhance overall well-being and support a healthier lifestyle. Given their versatility and health advantages, millet is a valuable addition to daily food choices.

Pearl Millet

Pearl millet (*Pennisetum glaucum*) is a promising nutritious plant, boasting a rich nutrient and bioactive profile that offers substantial health benefits.

The incorporation of pearl millet flour (PMF) in the preparation of cookies has been successfully achieved, resulting in products with a low gluten content. Replacing wheat flour with pearl millet flour in various bakery products is an effective strategy to enhance the intake of essential nutrients in the human diet [20]. The use of PMF as a substitute for wheat flour in cookie production significantly improves the nutritional profile and sensory quality characteristics of the final product.

Studies have shown that cookies made from a blend of wheat flour and PMF in a 40:60 ratio are well-accepted in terms of sensory parameters, making them both nutritionally beneficial and economically viable. Pearl millet, a low-cost grain, holds great potential for the development of nutritionally enriched value-added products aimed at combating malnutrition. The use of PMF in bakery products not only enhances their nutritional value but also provides a feasible solution for producing healthier baked goods.

Sorghum

There has been a significant increase in the research on the development of sorghum-based bakery products, particularly gluten-free (GF) bread. Reported that a wide range of commercial gluten-containing (GC) and GF food products have been studied globally. In particular, GF bread exhibits high variability in its nutritional content, with GF products often being high in fat and low in protein and dietary fiber.

The use of sorghum in GF bread has shown promise in improving both the nutritional content and physical and sensory properties. For example, developed a well-accepted GF bread using a high proportion of white sorghum flour or 100% bronze sorghum flour. However, they noted lower sensory acceptance of sorghum-based products compared to other cereals, partly because of the presence of tannins and phenolics in certain sorghum types. Nevertheless, some sorghum varieties, such as red sorghum BRS 332, have been well-accepted in GF bread formulations.

Sorghum with white pericarp can be used to replace wheat or rice flour in cakes without affecting the color, whereas brown and red sorghum can enhance the appearance of chocolate products. Sorghum-based cakes have been found to have good physical characteristics and high consumer acceptance, closely resembling traditional wheat or rice flour cakes, and have developed GF cakes with a high content of red sorghum flour, which were well received by Brazilian consumers despite their unfamiliarity with sorghum.

Cookies and biscuits can also benefit from the inclusion of sorghum flour. Researchers have developed biscuits using a mix of wheat flour and whole or extruded sorghum flour, resulting in improved resistant starch content and higher sensory acceptance, and created GF biscuits enriched with resistant starch from annealed white sorghum starch, although these had lower texture scores and overall acceptance compared to control samples.

A principal challenge in GF food production is achieving an acceptable texture because the absence of gluten often results in increased hardness. Despite extensive research, many GF products still fall short of sensory characteristics, particularly flavor and texture, for both celiac and non-celiac consumers.

Multi-Millet

Studies have concluded that bakery products made with multi-millet (Finger, Pearl, Sorghum) flour are acceptable at all tested levels (0%, 10%, and 30%) for cookies and bread. Incorporating 30% multi-millet flour significantly enhanced quality parameters, including moisture, ash, protein, fat, fiber, and total carbohydrates, compared to the control. Both cookies and bread with 30% multi-millet flour (T2) achieved the highest scores across all sensory parameters, indicating that these products were well-received by panelists and rated beyond the "like moderately" range. The inclusion of multi-millet flour not only improved the nutritional density of the products but also ensured that they were superior in sensory and nutritional quality compared to the control samples. This study suggests that multi-millet flour enhances both the sensory and nutritional values of baked goods, making them a desirable and safe option for consumption

Barley

Barley is commonly used to feed animals and malt for beer, but in recent years, it has also gained popularity in baking and extruded foods such as snacks, breads, and chapattis.

Barley is considered to be concentrated because of its high fat and carbohydrate content and low moisture levels, making it a good energy source. They typically contain 7–20% moisture, 30–70% sugar, and 30–60% fat. Industrial hard biscuits and tea cookies generally have 2.0–7.5% water, 5.3–15.4% protein, 3.1–30% fat, 2.2–3.1% dietary fiber, and 51–78% carbohydrates.

Muffins and cakes are popular owing to their ease of preparation and durability. The addition of barley flour to these products results in a darker color, reduced volume, and softer texture. Berglund et al. (2021) found that incorporating naked waxy barley flour or flakes in proportions from 26% to 100% improved sensory attributes, such as appearance, texture, taste, sweetness, and flavor, despite the darker color and decreased volume.

Explored muffins made with various bran types, including 100% oat bran, 40% barley bran, and 60% rice bran, and found that these muffins had comparable or superior qualities to commercial oat bran muffins. Muffins made with 100% barley flour were also successful, although variations in barley type affected the volume and density.

Studies have reported the addition of naked waxy barley fractions to yeast bread, biscuits, cookies, and muffins. They observed reduced volume in yeast bread but noted that sensory evaluations showed no significant differences between products with and without barley. The barley-enriched muffins were described as "moist."

Replacing wheat flour with barley flour dilutes the gluten content, which does not significantly affect cookie quality. Barley flour also provides functional benefits owing to its phenolic compounds, antioxidant activity, β-glucan, and dietary fiber. The choice of barley genotype and grain size affects the quality of the cookies. Studies have shown that increasing barley flour content, including higher β-glucan content, improves flavor, density, color, and nutritional value.

Barley flour also enhances the nutritional properties and color of the cakes. When added at 10-40%, sprouted barley flour improves nutritional content and physical properties, such as crumbly and soft texture, and has anti-staling effects. However, cakes made with sprouted barley flour may have weaker sensory characteristics than those made with pure wheat flour.

Incorporating malted barley bran or malt flour into cookies can enhance their nutritional profile and increase protein, fiber, and mineral content. Barley flour in cookies often results in a darker color, higher total phenolic content, and improved antioxidant activity compared with wheat-based cookies

Rice Flour

The use of rice-based flour as an alternative to Maida in gluten-free cake production presents notable technological and nutritional advantages. The addition of transglutaminase significantly affected brown rice cakes, leading to a decrease in crumb firmness and an increase in specific volume, enhancing the overall texture and quality of the cakes. However, this effect was not as pronounced in rice varieties with high phenolic contents. Baking resulted in a reduction in total phenolic compounds in brown, black, and red rice cakes by 39.8%, 9.5%, and 21.4%, respectively. Despite this decrease, the baking process increased the extractability of several phenolic acids and flavonoids, including quercetin and catechin, which enhanced the bioactive properties of cakes. Specifically, ferulic and p-coumaric acids were the only phenolic acids that were reduced after baking. Overall, the cakes exhibited an increased content of free phenolic compounds compared to rice flour, indicating that baking enhanced the availability of these beneficial compounds. Rice varieties rich in phenolic compounds, particularly pigmented varieties such as red rice, have emerged as important alternatives for producing gluten-free cakes. These varieties not only offer good technological properties but also ensure high levels of bioactive compounds, making them valuable ingredients for healthier gluten-free baked goods.

Maize

Maize, Also Known as corn, is a cereal grain that is a staple food in many parts of the world and is used as both a food crop and a fodder crop. The nutritional value of maize is extremely high. It has a high nutrient profile and provides a range of essential nutrients per 100 grams. It contains 72 g of carbohydrates, making it a significant source of energy. The protein content was 8.9 grams, whereas the fat content was relatively low at 5 g. Maize also offers 2.2 grams of dietary fiber, 2.4 grams of ash, and 11 grams of moisture. It is rich in minerals, including 350 mg of phosphorus, 16 mg of sodium, 115 mg of sulfur, 11 mg of calcium, 2.4 mg of iron, 287 mg of potassium, 140 mg of magnesium, and 0.15 mg of copper. Additionally, maize provides 0.43 mg of thiamine, 0.11 mg of riboflavin, 0.13 mg of vitamin C, and 1.80 mg of amino acids, contributing to its overall nutritional profile.

Wholegrain maize flour can be used to produce layer cakes with a similar volume and texture to cakes made with refined flour, although they have a darker crumb and slightly lower acceptability. Stabilizing treatments to reduce rancidity in germ oil results in harder and less voluminous cakes, but with acceptable quality. Stabilizing only the bran and germ with intense treatments produces lower-volume cakes owing to increased batter viscosity. Extrusion stabilization improves the acceptability of cakes made with wholegrain maize flour, demonstrating their viability as flour replacers in baking

Rye Flour

Rye (*Secale cereale* L.) has been cultivated since ancient times in Europe and is the second most important crop after wheat for the production of bread and other bakery products. Rye protein content (8–15%) is mainly influenced by genotype. They include albumins (29–40%), globulins (8–11%), prolamins (17–19%), and glutenin (9–15%). Rye has a slightly better amino acid profile than wheat because of its higher lysine content but lacks tryptophan and isoleucine. Its starch content was 55–65%, with an amylose content of 22–26%. Rye's lipid content (2–3%) and fatty acid composition were similar to those of wheat. It is rich in minerals (iron, zinc, manganese, and copper) and B vitamins, and is a good source of α-tocopherol.

Rye (*Secale cereale* L.), a key cereal, second only to wheat (Triticum aestivum L.) in bread production, is valued for its high dietary fiber, lysine content, and health benefits, although its bread-making performance is generally inferior to that of wheat flour. This study discusses the major constituents of rye—starch, proteins, and arabinoxylans—and their roles in bread-making. Rye proteins, which contribute minimally, lack the gas-retaining properties of wheat proteins, while the texture of the bread is primarily influenced by rye starch and arabinoxylan polysaccharides, which bind water and form structural networks. Despite the acknowledged health benefits of rye fiber, such as promoting normal bowel function, and potential advantages such as reducing colon cancer risk, curbing hunger, and lowering cholesterol, further research is needed to fully understand these effects and the interactions of rye components on dough and bread quality.

Chickpea Flour

Chickpeas are a valuable source of essential nutrients, including healthy fats, carbohydrates, minerals, vitamins, folate, proteins, and β-carotene, making them both affordable and easily accessible. They provide notable health advantages, such as reducing the risk of chronic conditions, such as cardiovascular disease and type-2 diabetes. Moreover, chickpeas contain bioactive peptides that may deliver beneficial effects such as antioxidant, anti-inflammatory, antihypertensive, and antidiabetic properties through enzymatic hydrolysis. Although certain peptides have shown potential health benefits, additional research is needed to validate their effects in humans and to refine processing methods to enhance their advantages while minimizing harmful compounds.

The use of pulses such as chickpeas in baking has gained importance because of their health benefits, including reducing obesity, type 2 diabetes, and colon cancer, as well as providing highly bioavailable proteins at a low cost. This enables the creation of innovative and nutritionally enhanced baked goods. Understanding the baking properties and rheology of chickpea flour can help the industry address the challenges related to non-gluten-forming ingredients. This study focused on summarizing these rheological properties and the health benefits associated with chickpea compounds, highlighting their potential for developing high-quality, nutritious products. Ongoing research into chickpea's industrial applications and health effects is expected to refine product development, particularly in bread formulations in which more than 15% of chickpea flour is used. The successful integration of chickpeas into baked goods can enhance nutritional value and address gluten-related processing challenges with positive consumer acceptance.

Chickpea flour-based flatbreads are typically hard and less elastic, which limits their appeal. The addition of barley flour improves the softness and elasticity of these breads while maintaining a low glycemic load. Although sensory attributes remain unchanged, combining barley and chickpea flour enhances the nutritional value by increasing fiber content and providing a complete amino acid profile. Such blends could improve daily fiber intake, support better glucose and cholesterol management, and potentially boost barley flour consumption, as flatbreads are staple foods in many cultures.

CONCLUSION

The exploration of alternative flours has revealed a diverse range of benefits and applications for baking, extending beyond traditional wheat flour. Each type of alternative flour offers unique functional and nutritional advantages that can significantly enhance the quality and health of baked goods.

Almond Flour provides a rich nutritional profile with a high-protein content, healthy fats, and essential vitamins and minerals. It is a valuable option for gluten-free baking, although its sensory attributes in baked goods vary depending on the proportion in the recipe. Oat Flour is known for its high β-glucan content, which contributes to heart health and improves digestion. Its application in baking, especially when incorporating sprouted oats, shows promising enhancements in dough handling and the final product texture. Millet Flour, including pearl millet, significantly contributes to the nutritional density of baked goods, improves fiber content, and offers a low glycemic index. It has been successfully used in cookies and other products, with both sensory and nutritional benefits. Sorghum Flour offers a viable gluten-free option with good nutritional and sensory qualities. While some sorghum varieties may affect texture and flavor, others show promise in improving the overall quality of gluten-free breads and cookies. Barley Flour has nutritional value because of its high fiber and phenolic content. It can alter the color and texture of baked goods but also provides functional benefits, such as improved antioxidant activity. Rice Flour is notable for its ability to enhance the texture and quality of gluten-free cakes, with specific varieties offering increased bioactive compounds and an improved crumb texture. Maize Flour maintains good textural properties in baked goods and can serve as a substitute for refined flours, although it might result in darker-colored products with slightly different sensory characteristics. Rye Flour is valued for its high dietary fiber content and beneficial compounds, although it requires careful handling to match the bread-making performance of wheat. Its potential health benefits make it a noteworthy alternative, although further research is required. Chickpea Flour provides a strong nutritional profile with a high-protein content and beneficial bioactive compounds. When combined with other flour, it can enhance the nutritional value of baked products while addressing the challenges related to gluten-free formulations.

In summary, the integration of these alternative flours into baking not only meets the growing consumer demand for healthier and more inclusive food options but also enriches the culinary landscape with diverse flavors and textures. Future research and development in this field should focus on optimizing the sensory and functional properties of these flours to maximize their potential for baked goods, ensuring that they meet both nutritional and consumer preferences. The continued exploration of alternative flours will contribute to a more varied and health-conscious food industry by addressing dietary needs and enhancing overall well-being.

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