Review Article

Composite Flour as an Innovative Food Ingredient in Bakery Products: A Review

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ABSTRACT

Composite flour, a widely utilised ingredient in food production, particularly in baking, offers an innovative approach to enhance the nutritional and technological properties of flour. This review was conducted to compare the quality attributes of various bakery products, including breads, biscuits, and cakes, produced using different types of composite flour. The review primarily focuses on evaluating the changes in physical, chemical, and sensory characteristics brought about by these composite flour in bakery products. Ultimately, the findings of the review reveal that composite flour significantly influences the textural properties, nutritional composition, and sensory acceptance of bakery products.

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1. Introduction

Baked goods have become an integral part of people's diet worldwide. The demand for convenient, quick snacks has increased, particularly in urban areas, where they serve as quick hunger-satisfying options or substitutes for full meals. To meet these demands, composite flour is utilised as an ingredient in producing such baked goods. Besides improving product quality, composite flour offers additional health benefits compared to products made solely with regular wheat flour (Marchini *et al.*, 2021; Oyeyinka *et al.*, 2021).

Composite flour in baking refers to a mixture of different types of flour or ingredients that are combined to create a blend with unique characteristics and benefits for baking applications (Noorfarahzilah *et al.*, 2014). The composition of composite flour can vary depending on the desired outcome and the specific recipe. Composite flour, which are widely used in bread production, primarily consist of a combination of cereals, tubers and roots, legumes, and fibres. These diverse sources contribute to the nutritional composition and functional properties of the composite flour (Ronie *et al.,* 2024).

Cereal grains such as millet, rice, wheat, oat, barley, rye, sorghum, and maize serve as a key component, providing carbohydrates, proteins, and various micronutrients (Graziano *et al.*, 2022; Adamczyk *et al.*, 2023). Tubers and roots like cocoyam, potato, cassava, and sweet potatoes add starch content and contribute to the texture and flavour of the bread (Olatunde *et al.*, 2019; Chikpah *et al.*, 2023). Legumes such as soybeans, chickpeas, peanuts, and lentils offer a significant source of plant-based proteins and dietary fibre, enhancing the nutritional value of the composite flour (Amadeu *et al.*, 2024). Lastly, fibres derived from sources like rice bran, seaweed powder, and cashew apple provide additional dietary fibre, promoting digestive health and providing texture to the bread (Mamat *et al.*, 2021; Mamat *et al.*, 2023). By incorporating these diverse ingredients into composite flour, bread producers can create products that offer enhanced nutritional profiles and appeal to consumers looking for a wider range of flavours, textures, and dietary benefits (HewaNadungodage *et al.*, 2022).

The advantages of using composite flour in baking are numerous (Figure 1). It can increase the fibre content of baked goods, improve nutritional value by adding essential vitamins, minerals, and antioxidants, and provide unique flavours and textures (Atudorei *et al.*, 2021). Composite flour can also offer options for individuals with dietary restrictions or preferences, such as those following a gluten-free, low-carb, or high-fibre diet. Moreover, composite flour is cost-effective, as it often incorporates more affordable non-wheat flour such as tapioca flour (Chisenga *et al.*, 2020), pumpkin flour (Aljahani, 2022), and banana flour (Ewunetu *et al.,* 2023). Partial utilisation or non-utilisation of wheat in flour production also aims to reduce the high cost associated with importing wheat for developing countries.

In baking, composite flour can be used as a substitute for traditional wheat flour or as an addition to enhance specific qualities of the final product (Xian *et al.*, 2024; Ling *et al.*, 2024). Bakers may need to adjust the proportions of ingredients, moisture levels, or leavening agents to achieve the desired texture and rise when using composite flour. It is important to follow formulations specifically designed for composite flour or to experiment with small batches to achieve the desired results. This versatile ingredient finds application in various baked goods, including bread, cake, biscuit, flatbread, muffins and the like.

This comprehensive review explores the utilisation of composite flour in the application of three major bakery products. The review investigates recent advancements in this area, with a specific emphasis on the effects of these ingredients on the physical characteristics, rheological properties of the dough, and the nutritional composition of breads, biscuits, and cakes. These three products were chosen because they are widely acknowledged as among the most popular items in the baking world.

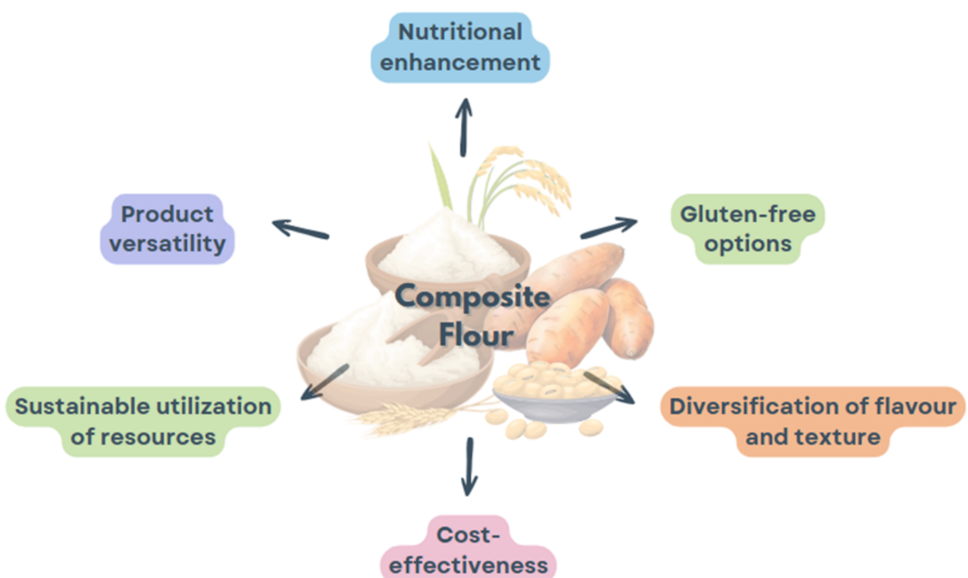

Figure 1 The positive impact of incorporating composite flour in bakery products

2. Bread

Bread is a staple food consumed by people all around the world. It is typically made from flour, water, yeast, and salt, although variations in ingredients and preparation methods exist across different cultures (Bredariol and Vanin, 2021). Bread undergoes a series of processes, including mixing, kneading, proofing, shaping, and baking. It is typically made using ingredients such as wheat flour, yeast, water, sugar, salt, and other necessary components (Olatidoye *et al.*, 2020). The presence of gluten-forming proteins in wheat flour gives it unique baking properties, making it a crucial ingredient in bread production (Chikpah *et al.*, 2021). Table 1 presents a summary of the effects of composite flour on bread properties.

The incorporation of pulse flour into food products is a widespread practice aimed at enhancing various aspects, including functional properties, nutritional profiles, product quality, and health benefits (Singh, 2017). Pulse flour, derived from legumes such as chickpeas, lentils, peas, and beans, offer unique characteristics that make them valuable ingredients in the food industry. In a recent study, Zhang *et al.* (2021) evaluated the impact of substituting whole wheat flour with various whole pulse flour (yellow pea, green pea, red lentil, and chickpea) at levels ranging from 0% to 25% on dough properties and bread quality. Among the various pulse flour tested, the composite flour containing yellow pea flour or chickpea flour showed promising potential for bread making. These composite flour exhibited favourable dough handling properties and resulted in high-quality bread products. However, increasing the substitution level of pulse flour decreased dough viscosity, stability, development time and bread volume, and accelerated bread retrogradation.

The growing consumer awareness of the importance of balanced nutrition has resulted in an increased demand for healthy foods in the market. In response to this demand, the development of multigrain bread has emerged as a primary focus (Mir *et al.*, 2023). The main objective of creating multigrain bread is to cater to the expanding need for a nutritious diet while considering economic factors and utilising lesser-known cereal grains. By incorporating a variety of grains into the bread formulation, multigrain bread offers a wider range of nutritional benefits, including increased fibre content, diverse micronutrients, and a more balanced nutrient profile. This development aligns with the goal of providing consumers with healthier options and making use of underutilised grains, contributing to a more sustainable and inclusive food system.

An emerging trend in bread production involves the utilisation of composite flour, which combines wheat flour with plants that have a high starch content. This innovative approach aims to enhance the nutritional composition and functional properties of bread. By incorporating these plant-based ingredients, which may include sources like tubers, legumes, or other starch-rich plants, into the bread formulation, the resulting composite flour can offer additional nutrients, dietary fibre, and unique flavours to the bread (Monthe *et al.*, 2019; Mehta *et al.* 2023). Tubers, such as sweet potatoes, have gained attention from food professionals due to their excellent health benefits and nutritional value. Sweet potatoes are rich in dietary fibre, vitamins, and minerals, including vitamin A, vitamin C, potassium, and manganese (Oloniyo *et al.*, 2021). Additionally, sweet potatoes have a lower glycemic index compared to regular potatoes, making them a favourable option for individuals concerned about blood sugar control (Chikpah *et al.*, 2020).

However, incorporating composite flour into bread recipes can result in noticeable physical alterations in both the dough and the final product. Chikpah *et al.* (2023) investigated the effects of incorporating orange-fleshed sweet potato (OFSP) and pumpkin flour into bread formulas. The researchers reported that the dough development time, crust redness, hardness, and chewiness values increased, while the optimum water absorption of dough, specific volume, lightness, springiness, and resilience of bread decreased significantly with increasing incorporation of OFSP and pumpkin flour in the bread formula. This indicates that the addition of OFSP and pumpkin flour had a negative impact on bread properties.

While wheat flour is widely used in breadmaking due to its excellent baking qualities, it has some limitations pertaining to health-promoting properties. Wheat flour is relatively low in bioactive compounds such as vitamins, beta-carotene, polyphenols, flavonoids, and dietary fibre. Dietary fibre enrichment through the use of composite flour offers a creative way to boost the nutritional value of bread. This method involves incorporating various sources of dietary fibre, including whole grains, seeds, bran, or other fibre-rich ingredients, into the bread recipe. By doing so, the resulting bread product can have a substantially higher fibre content compared to traditional bread recipes (Haini *et al.*, 2021; Mamat *et al.*, 2023; Noraidah *et al.,* 2023). In a study by Haini *et al.* (2022), the effects of incorporating resistant starch, particularly high-amylose maize starch (HM), were investigated by substituting 30% of wheat flour in Chinese steamed bun recipes. The study focused on evaluating the postprandial glycemic response in healthy human subjects through glycemic index analysis. The findings indicated that the incorporation of HM into the buns could offer potential benefits as a dietary intervention for managing glycemic control.

Extensive research has been conducted by researchers on the utilisation of fruits and vegetables as functional composite flour ingredients in bread formulations. These studies explore the potential applications of incorporating fruits and vegetables into bread recipes to enhance both the nutritional value and functional properties of the final product (Vijayendra and Sreedhar, 2023). By incorporating fruits and vegetables such as bananas (Ewunetu *et al.*, 2023), pumpkins (Pourmohammadi *et al.*, 2020), carrots (Raczyk *et al.*, 2022), or beetroot (Adamczyk *et al.* 2023) into bread formulations, researchers aim to harness the added vitamins, minerals, antioxidants, and dietary fibre present in these ingredients (Amoah *et al.*, 2022). Furthermore, fruits and vegetables can contribute unique flavours, colours, and textures, thereby enhancing the sensory appeal of the bread.

Various types of seed flour, such as pumpkin, watermelon, buckwheat, chia, and others, are being utilised as substitutes for a portion of wheat flour in the production of wheat bread (Adamczyk *et al.*, 2021; Litvynchuk *et al.*, 2022). This innovative approach involves incorporating these seed flour into the bread-making process to enhance its nutritional composition and introduce unique flavours and textures. By replacing a portion of the wheat flour with seed flour, the bread can benefit from the nutritional richness of the seeds, including their high content of vitamins, minerals, healthy fats, and dietary fibre (Graziano *et al.*, 2022). Moreover, the inclusion of seed flour adds diversity to the bread, creating a more appealing and wholesome product for consumers seeking a broader range of flavours and textures in their baked goods. The utilisation of seed flour in wheat bread technology provides an opportunity to improve the nutritional profile and overall quality of bread, catering to the evolving preferences and demands of health-conscious individuals.

Table 1 Other flour used to substitute wheat flour in bread production

Flour used	Substitution level	Quality improved	References
Yellow pea, green pea, red lentil, chickpea	0–25%	Protein, ash	Zhang *et al.*, (2021)
Soya bean, oats, fenugreek seeds, flaxseed, sesame seeds	5 - 20%	Protein, fat, dietary fibre, dough strength, overall quality	Indrani *et al.*, (2010)
Peeled and unpeeled sweet potato	0 - 100%.	Dough stability	Chikpah *et al.*, (2020)
Germinated bean flour	5 -25%	Volume, porosity, elasticity, firmness, gumminess and chewiness	Atudorei *et al.*, (2021)
Sweet potato, pumpkin flour.	10– 50%	Staling rate	Chikpah *et al.*, (2023)
Rice flour, green gram flour, potato flour	0 – 55%	Overall acceptability	Chandra *et al.*, (2015)

3. Biscuits

Biscuits, popular types of baked goods, have been subject to exploration and modification using composite flour to achieve desired characteristics. Various types of composite flour, with or without wheat flour, have been utilised to enhance the physical properties, functional properties, and nutritional value of biscuits (Chandra *et al.*, 2015; Melese and Keyata, 2022). By incorporating composite flour into biscuit recipes, it is possible to enhance their nutritional value while still ensuring consumer acceptability (Table 2). For example, the inclusion of lemon basil, scent leaf powders, and cashew kernel flour alongside wheat flour at 1.0%, 2.5%, and 5.0% respectively, results in biscuits with higher levels of ash, crude protein, fat, and crude fibre compared to the control. Additionally, biscuits supplemented with composite mix flour exhibited a decrease in hardness, indicating a softer texture (Ujong *et al.*, 2023).

Gbenga-Fabusiwa *et al.* (2018a) explored the sensory characteristics, nutritional attributes, and glycemic index of biscuits made from a blend of pigeon pea (PP) and wheat flour (WF) in a group of healthy individuals. The findings showed that composite biscuits contain high levels of crude fibre, protein, and amylose, yet exhibit a low glycemic index. Sensory evaluation indicates that the most acceptable biscuit is made from a ratio of pigeon pea-wheat composite flour at 25:75 compared to other proportions. This suggests that a higher percentage of pigeon pea flour can be incorporated into biscuits, but the acceptability among consumers may decrease. Furthermore, Gbenga-Fabusiwa *et al.* (2018b) examined the phenolic content and antioxidant properties of biscuits made from a combination of pigeon pea and wheat flour. The biscuits were created by replacing wheat flour (WF) with pigeon pea flour (PP) in varying proportions: 100:0 (0-PP), 75:25 (25-PP), 50:50 (50-PP), 25:75 (75-PP), and 0:100 (100-PP). The findings showed that the flour mixtures had higher overall phenol and flavonoid levels, along with greater antioxidant activity compared to the biscuit blends. Nonetheless, both the 100-PP flour and 100-PP biscuit blends exhibited the highest phenolic content and antioxidant properties among their respective blends.

Table 2 Alternative flour for substituting wheat flour in biscuit production

Type of flour	Substitution level	Quality improved	References
Pumpkin, common bean	5 – 20%	Protein, fat, ash, crude fibre	Melese and Keyata, (2022)
Sweet potato flour, soybean flour.	25 – 400g	Moisture, fat, protein, fibre, copper, manganese, calcium, magnesium, potassium	Roger *et al*., (2022)
Lemon basil powder, scent leaf powders, and cashew kernel flour	0 – 20%	Ash, crude protein, fat, crude fibre, calcium, sodium, magnesium, phytochemical	Ujong *et al*., (2023)
Pigeon pea	0 – 100%	Crude fibre, protein, amylose, glycemic index, taste, general acceptability	Gbenga-Fabusiwa *et al*., (2018)
Pumpkin seed oil press cake	0 – 60%	Taste, texture	Jukić *et al*., (2018)
Cooking banana, pigeon pea, sweet potato	10 – 80%	Crude protein, crude fibre, ash contents, dietary fibre content, hardness	Adeola and Ohizua, (2018)
Soy okara, tigernut residues	10 – 40%	Protein, fat, carbohydrate, fibre, magnesium, sodium, iron.	Agu *et al*., (2023)
Flaxseed powder, inulin	Inulin (0–20%); flaxseed powder (0–70%)	Ash, protein, moisture, water activity, hardness, cohesiveness, gumminess, adhesiveness.	Nasiri *et al*., (2023)
Buckwheat flour and almond flour	10 – 30%	Protein, fat, ash, fibre content	Masoodi *et al*., (2023)
Corn-based flour, crushed, shell-less walnuts, peanuts	5 - 20%	Fat, protein, crude fibre, ash	Olaimat *et al*., (2023)
Multi-millet flour	0 – 100%	Fat, ash, fibre, total phenolic content, antioxidant activity	Arepally *et al*., (2023)

There is also a growing trend of using composite flour made from agricultural by-products to minimise waste and promote environmental sustainability. For example, biscuits prepared from finger millet seed coat-based composite flour have been investigated. The seed coat, a by-product of millet milling, is edible and rich in phytochemicals, including dietary fibre and polyphenols. Research showed that these biscuits have a crisp texture, higher breaking strength compared to control biscuits, a mild-gray colour, and increased protein, dietary fibre, and calcium content (Krishnan *et al*., 2011).

Similarly, a study by Jukić *et al.* (2018) evaluated the quality of biscuits produced from composite blends of pumpkin seed oil press cake flour (PSOPC), a by-product of pumpkin oil production, and wheat flour. The research aimed to determine the potential use of pumpkin seed oil press cake flour as a wheat flour substitute in biscuit production to reduce the need for shortening. Biscuits were made using composite mixtures of plain white flour and PSOPC flour at different ratios: 100:0, 80:20, 60:40, and 40:60. The findings demonstrate that the composite flour decreases the biscuit diameter, height, and volume while creating a softer texture. It also contributes to a greenish colour and imparts a pleasant taste of roasted pumpkin seeds, thereby enhancing the texture and sensory properties of the biscuits.

Composite cookies can be created not only by blending wheat flour with a single type of non-wheat flour but also by combining multiple, different types of flour to achieve optimal outcomes. Chandra *et al.* (2015) used four types of flour in biscuit production wheat flour, rice flour, green gram flour, and potato flour in the proportionsof 100:0:0:0, 85:5:5:5, 70:10:10:10, and 55:15:15:15. They observed that greater incorporation of non-wheat flour led to improvements in various functional properties, including swelling capacity, water and oil absorption, emulsion activity and stability, foam capacity and stability, gelatinization temperature, least gelation concentration, and bulk density. Sensory evaluation revealed that the biscuit with the highest percentage of incorporation of other flour was the most preferred due to its colour, flavour, and taste.

Adeola and Ohizua (2018) conducted a study to examine the impact of 14 different flour blends of unripe cooking banana (UBF), pigeon pea (PPF), and sweet potato (SPF) on the physical properties, nutrient composition, and sensory characteristics of biscuits. They discovered that increasing the proportion of UBF, PPF, and PPF in the blends led to a decrease in the hardness of the biscuit samples. Similarly, the fracturability of the biscuits decreased with higher amounts of UBF. The nutrient composition of the biscuits varied significantly ($p<0.05$), with higher levels of crude protein, crude fibre, ash content, and dietary fibre observed as the PPF level increased. The biscuits were also found to be a rich source of magnesium and had a favourable sodium/potassium (Na/K) ratio. These biscuits were favoured in terms of shape, mouthfeel, taste, crunchiness, and overall acceptability.

A recent study conducted by Agu *et al.* (2023) explored the sensory and physicochemical properties of biscuits made from a combination of whole wheat, soy okara, and tigernut residue flour. The findings revealed that substituting wheat flour with soy okara and tigernut residue flour produced highly acceptable and nutritious biscuits. These biscuits outperformed a 100% whole wheat biscuit across all assessed sensory attributes. The research found that replacing wheat flour with a mix of soy okara and tigernut residue flour at a ratio of 60:20.98:19.02 resulted in the most liked biscuits across all sensory qualities evaluated. Furthermore, the composite blend used in the biscuits provided significant amounts of protein, beneficial fats, limited carbohydrates, ample fibre, as well as essential minerals such as magnesium, calcium, phosphorus, sodium, and iron. Consequently, these biscuits offer a potential solution for addressing malnutrition. Moreover, the incorporation of soy okara and tigernut residue did not negatively impact the physical properties of the biscuits. Therefore, soy okara and tigernut residue present viable alternatives to wheat flour, alleviating the strain on foreign reserves used for wheat importation.

Extensive research has established that individuals with wheat allergy and celiac disease must avoid consuming gluten due to its detrimental effects on villous atrophy (Abdi *et al.* 2023). Consequently, there has been a surge in the development of alternative food products that cater to gluten-free diets. In particular, the utilisation of composite flour in the production of gluten-free biscuits has garnered significant attention in recent times (Nasiri *et al.*, 2023; Masoodi *et al.*, 2023; Olaimat *et al.*, 2023). Millet is recognised for its potential to offer various health benefits to consumers, particularly in addressing celiac disease and gastrointestinal issues. Its usage has gained attention due to its unique properties and nutritional composition (Yousaf *et al.*, 2021).

A study conducted by Arepally *et al.* (2023) examined the substitution of wheat flour (WF) with multi-millet flour (MMF) at different levels (0%, 20%, 40%, 60%, 80%, and 100%) in the production of multi-millet biscuits. The MMF used in the study was a combination of barnyard, finger, kodo, and pearl millet in equal proportions. Results showed that biscuits made with MMF had significantly higher levels of fat, ash, and fibre compared to the control group (100% WF). Additionally, the 100% MMF-based biscuit exhibited a greater total phenolic content and antioxidant activity compared to the control biscuit. Sensory analysis revealed that biscuits containing 40% MMF were the most acceptable among all the samples tested. This study provides valuable insights into the utilization of MMF for producing nutritious multi-millet-based biscuits.

4. Cakes

Cake, a popular baked product, typically consists of flour, eggs, sugar, shortening, baking powder, and essence as its principal ingredients. While the conventional practice involves using wheat flour to prepare plain cakes, the use of composite flour is prevalent in developing countries to create nutritionally balanced cakes. In the past, there has been considerable research attention directed towards studying the utilisation of different types of composite flour, such as those derived from cereals (maize, rice, sorghum) (Cayres *et al.*, 2021), pseudocereals (amaranth, buckwheat, quinoa) (García-Segovia *et al.*, 2017; Carmona-Garcia *et al.*, 2022), pulses (chickpea, pigeon pea) (Ozkahraman *et al.*, 2016), fruit seeds (apricot, sour cherry, pomegranate) (Aĝirbaş *et al.*, 2021) and tubers (sweet potato, potato) (Olatunde *et al.*, 2019), specifically in the context of cake production.

The addition of composite flour to cake recipes offers a means to adjust and improve several aspects, such as colour, flavour, texture, functional properties, and nutritional value (Table 4). Studies have shown that cakes incorporating composite flour, such as a combination of wheat flour, chickpea flour, and rice flour, demonstrate increased moisture, protein, ash, fat, and carbohydrate content when compared to cakes made exclusively with wheat flour (Olakanmi *et al.*, 2022). Furthermore, the incorporation of chickpea flour in composite cakes has been found to result in increased volume, primarily attributed to its higher fibre content. Higher fibre content can increase cake volume by improving water retention, supporting the cake's structure, and enhancing gas retention during baking. Conversely, a reduction in the proportion of rice flour has been associated with decreased cake volume. Additionally, in terms of colour, flavour, texture, and overall acceptance, the cake made with 70% wheat flour, 15% rice flour, and 15% chickpea flour showed significant improvement over cakes made with other composite flour percentages (Rahut *et al.*, 2012).

The inclusion of African yam bean flour (AYBF) in cake formulations alongside wheat flour (WF) at various ratios (WF/AYBF 100:0, 80:20, 75:25, 50:50, 0:100) results in notable changes to the nutritional composition. Compared to cakes made solely with wheat flour, incorporating AYBF increases the protein, crude fibre, and ash content (Alozie *et al.*, 2011). This is significant because wheat flour is limited in lysine and tryptophan but rich in sulfur-containing amino acids like methionine and cysteine, while AYBF exhibits the opposite composition. The complementary nature of proteins in WF and AYBF leads to cakes with improved nutritional quality. These factors contribute to the cakes' nutritional significance. Increased dietary fibre intake has been associated with a reduced prevalence of chronic diseases. Therefore, the incorporation of AYBF not only enhances the nutritional value of the cakes but also provides potential health benefits.

Mango kernels are often considered waste, but their flour holds promise as a viable alternative to wheat flour in various food applications. Adding mango kernel flour to wheat flour-based cake formulations at different ratios (WF/MKF 100:0, 90:10, 80:20, 70:30, 60: 40) yields cakes with a higher energy content compared to those made solely with wheat flour. The addition of mango kernel flour also increases the fibre, ash, and fat in these cakes. Notably, colour analysis reveals that the inclusion of mango kernel flour darkens both the crust and crumb colour of the cakes. In terms of sensory evaluation, cakes containing 20% mango kernel flour are deemed the most acceptable. Storage stability tests further demonstrate that these cakes can be stored for 7 to 10 days without the need for preservatives, showing improved stability compared to cakes made solely with wheat flour (Das *et al.*, 2019).

In a study conducted by García-Segovia *et al.* (2017), the researchers investigated the effects of partially replacing wheat flour with a composite mix flour composed of 52% quinoa, 22% dry pea, 25% dry carrot, and 1% tocte in cake formulations. The replacement levels were set at three different levels: 0%, 10%, and 30%. The results from the study revealed that the incorporation of this composite flour mixture as a partial substitute for wheat flour had significant implications for the colour, porosity, texture, and proximate composition of sponge cakes. These modifications showed potential for improving the nutritional, sensory, and physicochemical properties of the cakes.

Incorporating soybean flour into cake formulations as part of a composite flour mixture enhances the nutritional value of the cakes in comparison to those made exclusively with wheat flour. The addition of soybean flour results in increased protein and fat content while reducing carbohydrate content. Sensory analysis indicates that cakes with a composition of 70% wheat flour and 30% soybeans are more widely accepted than cakes made solely with wheat flour (Rita *et al.*, 2011).

Table 3 Wheat flour replacement in cake production

Flour added	Substitution level	Quality improved	References
Quinoa, pea, carrot, tocte	0 - 30%	Protein, hardness	García-Segovia *et al.*, (2017)
Lentil, chickpea, pea	10%	Texture, specific volume	Ozkahraman *et al.*, (2016)
Apricot seed, sour cherry seed, pomegranate seed, pumpkin seed	5 – 15%	Texture	Aĝirbaş *et al.* (2021)
Pigeon pea, sweet potato	10 – 20%	Proximate content, phytate	Olatunde *et al.*, (2019)
Chickpea, rice flour	5 – 25%	Moisture, protein, fat, ash, carbohydrate, volume, specific volume	Rahut *et al.*, (2012)
African yam bean	0 – 100%	Protein content, ash, crude fibre	Alozie *et al.*, (2011)
Mango kernel	10 – 40%	Fat, ash, crude fibre, stability	Das *et al.*, (2019)

Recent research suggests that banana blossom flour holds promise as a substitute for wheat flour in cake production, offering notable enhancements in physicochemical, nutritional, and functional attributes. Banana blossom flour is characterised by its richness in protein, minerals, and dietary fibre. Through various pre-treatment methods, banana blossom flour exhibits improved colour retention, elevated levels of iron, potassium, calcium, and enhanced functional properties, while retaining its physical characteristics and maintaining consumer acceptability (Tasnim *et al.*, 2020).

Furthermore, research has demonstrated that the incorporation of germinated bean flour and cowpea flour as partial replacements for wheat flour in cake recipes can be done without compromising the quality of the final product. For example, completely substituting wheat flour with germinated bean flour produces cakes of good quality with an extended shelf life. Similarly, substituting 50% of wheat flour with cowpea flour yields satisfactory cakes. Cakes made entirely with germinated bean flour exhibit reduced staling rates compared to those made solely with wheat flour by increasing enzyme activity, improving water retention, and enhancing emulsification. These findings suggest that the resulting cakes have a longer shelf life and maintain their quality, making them suitable for transportation purposes (Atef *et al.*, 2011).

In the pursuit of enhancing the bioactive compounds and antioxidant activity of cake, El-Beltagi *et al.* (2023) employed fruit flour derived from prickly pear peel (PPPF). The PPPF was found to be a valuable source of dietary fibres, which could improve the nutritional properties of the cake and contribute to the creation of a beneficial product. The study also revealed that incorporating 5%, 10%, and 15% of PPPF into the cake batter significantly increased the concentration of total polyphenols and flavonoids after baking, thereby enhancing the recovery of bioactive substances. Among the tested recipes, substituting 10% of wheat flour with PPPF resulted in the most pronounced flavour and yielded the best outcomes in terms of specific volume. Moreover, a trained panel concluded that the cake containing 10% PPPF obtained the highest sensory analysis scores for appearance, flavour, and texture. The findings highlight that PPPF serves as a rich source of natural antioxidants.

5. Future challenges

The future of composite flour applications in food products presents both challenges and opportunities for improvement across several key areas. One significant challenge lies in optimising formulations to achieve the proper balance of composite flour components, such as wheat flour and alternative flour to enhance nutritional profiles while maintaining acceptable sensory qualities such as taste, texture, and appearance. Future research efforts should prioritise the development of optimised formulations that improve nutritional benefits without compromising product quality. Texture and sensory acceptance are also critical considerations for composite flour-based products (Chen and Rosenthal, 2015; Moskowitz, 2017). Changes in texture or flavour profiles compared to traditional products can impact consumer acceptance. Addressing these sensory challenges through ingredient modifications or innovative processing techniques will be essential to enhance overall consumer satisfaction and market acceptance of composite flour products.

Moreover, making composite flour depends on guaranteeing enough availability and supply of non-wheat crops. This calls for advancing supply chains, supporting agricultural practices that increase the output of crops including pulses, millet, sorghum, and legumes, thereby increasing their cultivation. These crops can thus be consistently included into composite flour, providing substitutes for wheat and thereby improving the nutritional content and variety of food products.

Another challenge in composite flour applications is ensuring shelf life and stability. Variations in moisture content (due to storage conditions, ingredient composition, processing methods, and packaging) and lipid oxidation rates (related to oxygen exposure, temperature, light, moisture, and metal ions) can affect product quality over time (Barden and Decker, 2016; Ahmed *et al.*, 2016). Future research should explore novel preservation methods or innovative packaging technologies to extend shelf life without relying on artificial additives, thereby enhancing the overall sustainability of composite flour-based products. The functional properties of composite flour can differ from traditional flour, affecting dough handling, baking performance, and final product quality. Future studies should focus on enhancing the functional properties of composite flour through ingredient modifications or innovative processing techniques to ensure consistent and superior performance in food applications.

Consumer education and perception play a crucial role in the adoption of composite flour-based products (Piha *et al.*, 2018). Educating consumers about the benefits of composite flour and addressing any misconceptions or resistance towards alternative ingredients will be essential for market acceptance. Future efforts should emphasise on transparent labelling and clear communication of nutritional benefits to build trust and promote widespread adoption of composite flour products (Asioli *et al.*, 2017). Lastly, addressing regulatory considerations related to labelling, nutritional claims, and food safety standards for composite flour-based products is essential (Onyeaka *et al.*, 2023). Future research efforts should align with regulatory guidelines and standards to ensure product compliance and consumer safety, paving the way for successful integration of composite flour applications in the food industry.

6. Conclusion

Composite flour is a versatile ingredient that combines different flour or ingredients in baking to enhance the nutritional value, texture, flavour, and functionality of baked goods. It provides the opportunity to increase fibre content, incorporate essential nutrients, and add beneficial compounds. It is particularly useful in gluten-free baking, allowing the creation of blends that mimic the texture and flavour of wheat-based products. Composite flour influence the texture and structure of baked goods, enabling bakers to achieve specific characteristics. They also contribute unique flavours, such as those from nut flour or ancient grains. Composite flour have functional properties that affect moisture retention and dough handling. Recipe adaptation is necessary to obtain the desirable final product. Consumer acceptance is important, and understanding preferences helps in efforts to refine composite flour blends. Overall, composite flour offers bakers the ability to create healthier, flavourful, and versatile baked goods while meeting various dietary needs and preferences.

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