ADVANCEMENTS IN COMPOSITE FLOURS: APPLICATIONS, NUTRITIONAL BENEFITS, AND PROCESSING TECHNIQUES

**Abstract**

Composite flours, produced by blending various types of flours such as grains, tubers, and legumes, represent a promising alternative to traditional wheat flour. These blends enhance the nutritional profile of food products by increasing levels of protein, dietary fiber, vitamins, and antioxidants, sourced from ingredients like millet, quinoa, amaranth, and chickpeas. This review examines the impact of different processing techniques including baking, frying, roasting, and extrusion, on the retention and bioavailability of essential nutrients in foods made from composite flours. Additionally, the effects of storage conditions, moisture management, and packaging on product quality, sensory attributes, and shelf life are discussed. The study highlights the functional properties of composite flours, their diverse applications in food production, and their potential to improve food security, particularly in regions with limited access to quality grains and proteins. Challenges related to ingredient compatibility, processing optimization, and consumer acceptance are also addressed to provide a comprehensive perspective on the development and utilization of composite flours.

Key words: Composite flour, storage, frying, extrusion

**1. Introduction**

Composite flours, formulated by blending various flours derived from tubers, grains, legumes, and pseudocereals, are gaining significant attention as viable alternatives to traditional wheat flour in food production (Nyembwe et al., 2018; Emmanuel et al., 2019). These blends aim to improve the nutritional quality and functional properties of food products while reducing dependence on wheat, which is increasingly vulnerable to climate change and global market fluctuations (Awolu et al., 2017). Common staple crops such as cassava, sweet potato, maize, and rice provide affordable and carbohydrate-rich sources; however, they often lack essential nutrients, contributing to malnutrition concerns (Chandrasekara and Joseph, 2016; Oyeyinka et al., 2020; Olamiti and Ramashia, 2024). The inclusion of legumes and pseudocereals enriches composite flours with higher levels of protein, dietary fiber, and minerals, thereby enhancing their nutritional profile (Pakhare et al., 2018). Furthermore, processing methods such as baking, frying, and extrusion significantly influence the retention and bioavailability of nutrients, as well as the sensory and functional attributes of the final products (Sruthy et al., 2023; Li et al., 2017). This review comprehensively examines the nutritional advantages of incorporating tubers and cereals in composite flours, evaluates the effects of various processing techniques on nutrient preservation and product quality, and discusses the impact of storage conditions on shelf life and sensory characteristics.

**2. Nutritional, Functional, and Sensory Benefits of Composite Flours**

**2.1 Nutritional Benefits:**

The choice of ingredients in composite flours (CF) significantly influences the nutritional composition and functional properties of the resulting food products. The incorporation of legumes and seeds enhances the protein, dietary fiber, and healthy lipid content, while also contributing positively to flavor and texture profiles (Sharma et al., 2013; Schmidt and Oliveira, 2023). For instance, soy flour enrichment in wheat bread has been shown to increase mineral content and improve nutritional quality (Mandula et al., 2018). On average, composite flours provide approximately 15 g of protein per 100 g, compared to 10 g in conventional wheat flour, supporting muscle maintenance and repair (Oyeyinka et al., 2023). Additionally, CFs contain around 2 g of beneficial fats per 100 g, double the amount found in wheat flour, which facilitates the absorption of fat-soluble vitamins (Aslam et al., 2014). The fiber content in composite flours is also substantially higher approximately 8 g per 100 g compared to 2 g in wheat offering benefits for digestive health, weight management, and reducing the risk of type 2 diabetes (Adebayo et al., 2023).

Research by Bello et al. (2019) demonstrated that blending wheat with pigeon pea and raw plantain significantly enhanced protein and fiber levels, thereby improving the overall nutritional profile of the flour. Furthermore, such composite blends contribute to decreasing dependence on imported grains, supporting local agricultural sustainability (Omeire et al., 2014, Emmanuel et al. 2019). Importantly, composite flours often contain anti-nutritional factors such as hydrogen cyanide and oxalates that can inhibit nutrient absorption; however, appropriate processing techniques effectively reduce these compounds, ensuring food safety and nutritional efficacy (Bello et al., 2019). Thus, a comprehensive understanding of both beneficial nutrients and potential anti-nutrients is critical for optimizing composite flour formulations.

**2.2 Bioactive and Antioxidant Properties**

Composite flours provide a balanced nutritional profile that can help alleviate hunger and malnutrition, particularly in vulnerable populations (Pakhare et al., 2018). They typically exhibit a lower glycemic index compared to pure wheat flour, which is beneficial for individuals managing blood glucose levels, such as those with diabetes. Moreover, composite flours are enriched with essential vitamins including B-complex, A, and C that support immune function, enhance metabolic processes, and mitigate oxidative stress (Rashwan et al., 2021).

Recent studies highlight the potential of fortifying composite flours to further improve their health-promoting properties. For example, Akinwotu et al. (2024) demonstrated that the supplementation of cassava mash with coconut and cocoa enhanced its antioxidant capacity and mineral content. Similarly, Hoehnel et al. (2022) reported that pasta products enriched with composite flours exhibited superior protein quality relative to traditional wheat pasta. Additionally, legumes incorporated in composite flours contain bioactive compounds such as flavonoids, phenolic acids, and carotenoids, which possess antioxidant and anti-inflammatory effects (Tang et al., 2015). Beyond their nutritional advantages, these compounds contribute to improved flavor, texture, and extended shelf life in composite flour-based food products (Tortoe et al., 2019).

**2.3 Functional Benefits**

Composite flours also improve the performance and texture of food during cooking. Food ingredients like legumes and tubers add better texture and stabilize the product. Bello et al. (2019) found that CF had superior water and oil adsorption and swelling properties, stabilizing food structure and mouthfeel. Tharise et al. (2014) experimented with blends of cassava, rice, soybean, and potato starches, reporting that they performed comparably to wheat flour when cooked. These starch blends also demonstrated good viscosity, which influences how food thickens and maintains its shape, making them suitable for use in a wide range of recipes.

Sunil et al. (2021) also studied composite flours of wheat, pumpkin flour, and pumpkin seed flour. They reported enhanced swelling, water and oil absorptions, foam quality, and density. All these properties help in enhancing shelf life and texture quality of end products, making CF suitable for the production of a vast array of food.

**2.3.1 Functional Properties of Composite Flours: Influence of Ingredients on Product Quality**

Composite flours are increasingly utilized in food manufacturing due to their enhanced nutritional qualities and their ability to diversify food product development. The functional performance of composite flours during cooking or baking largely depends on their compositional makeup, including the proportions of carbohydrates, proteins, lipids, moisture, dietary fiber, minerals, and any added ingredients such as sugar substitutes (Awuchi, 2017; Awuchi & Echeta, 2019). These components significantly influence key functional properties such as water absorption capacity, viscosity, texture, and color. These properties are critical because they directly affect the sensory attributes, appearance, and structural integrity of the final food products (Bello et al., 2019).

**(i) Water Absorption Capacity (WAC)**

Water absorption capacity is a critical functional property that determines how well dough retains moisture during mixing and cooking processes (Godwill et al., 2019). The ability of a flour blend to absorb water depends on the type and composition of the constituent flours. Flours with higher dietary fiber content, such as those from chickpeas or other legumes, exhibit greater water absorption than conventional wheat flour (Source et al., 2019). For example, the inclusion of chickpea flour in wheat flour mixtures increases water absorption due to the elevated protein and fiber levels in chickpeas.

The amount of water absorbed directly influences dough consistency and the quality of the final product. Insufficient water absorption results in stiff, less elastic dough that poorly rises, yielding dense baked goods that stale rapidly. Conversely, excessive water absorption produces sticky dough with reduced shelf life due to faster deterioration (Godwill et al., 2019). Chandra et al. (2015) demonstrated that blends of wheat, rice, green gram, and potato flours resulted in biscuits with improved tenderness and prolonged freshness.

Viscosity measures the thickness or thinness of a heated flour mixture. Gelation occurs during heating as starch molecules absorb water and form a gel network, which is particularly important in food products such as soups and sauces where texture consistency is key (Godwill et al., 2019). The paste’s thickness depends on the starch composition, specifically the relative amounts of amylose and amylopectin. Flours rich in amylopectin, such as rice and potato flours, tend to form thicker, stickier pastes compared to wheat flour. For instance, Zhang et al. (2021) observed that rice flour produces a thicker and more adhesive dough, suitable for noodle production. Similarly, Getachew and Admassu (2022) found that combining wheat flour with oat and moringa flours increased dough viscosity, enhancing its suitability for nutrient-enriched noodles.

Rheology refers to the deformation, flow, and handling properties of dough during mixing and shaping (Godwill et al., 2019). These characteristics influence dough workability and the quality of the finished product. Gluten, a protein complex in wheat, plays a pivotal role in dough rheology, imparting elasticity and structure. The addition of non-wheat flours can alter gluten strength, often softening the dough, which may be compensated by incorporating binding agents to stabilize dough structure. For example, Getachew and Admassu (2022) reported that incorporating moringa and oat flours with wheat improved noodle dough quality. Conversely, Adegoke et al. (2015) found that adding breadfruit flour to wheat dough negatively affected dough properties and compromised bread quality. These findings highlight the importance of understanding flour interactions to optimize composite flour formulations for specific food applications.

**(iv) Swelling Capacity**

Among the functional properties of composite flours, swelling capacity is particularly important. It refers to the extent to which flour granules expand upon hydration and heating (Iwe et al., 2016). This property is primarily influenced by the starch composition, especially the amylose-to-amylopectin ratio, with flours high in amylopectin exhibiting greater swelling potential. Swelling capacity significantly affects the softness, texture, and moisture retention of baked products. Salunkhe and Immanuel (2022) demonstrated that the inclusion of rice, green gram, and potato flours enhanced swelling capacity, while higher proportions of wheat flour tended to reduce it. Similarly, Sunil et al. (2021) evaluated composite flours composed of wheat, pumpkin, and pumpkin seed flours and found that the blend with the highest content of pumpkin and pumpkin seed flour showed superior functional properties, including swelling capacity.

**2.4 Sensory Perception of Foods Prepared from Composite Flours**

The incorporation of flours derived from non-wheat sources significantly influences the flavor, texture, and appearance of food products. Legume flours such as those from lentils and chickpeas impart characteristic nutty or earthy flavors. Chickpea flour typically exhibits a mild sweet and nutty profile, whereas lentil flour has a more pronounced earthy taste. These distinct flavors can be balanced by incorporating complementary ingredients, such as spices in savory dishes or vanilla in sweet preparations (Olamiti & Ramashia, 2024). Texturally, legume flours tend to produce denser or slightly coarser products; improper formulation may result in dryness or grittiness. For example, Bojnanska et al. (2021) reported that the inclusion of chickpea, lentil, and bean flours altered dough texture and impacted overall bread quality. Some legumes may also introduce a bitter or “beany” aftertaste, which can be mitigated by blending with milder-flavored flours such as rice or quinoa. Abu et al. (2021) demonstrated that balanced flour combinations enhance both flavor and mouthfeel.

Colour is another important quality attribute affected by composite flours. Flours derived from yellow or orange crops, such as sweet potato or maize, can impart noticeable coloration to baked goods. Bibiana et al. (2014) observed that high proportions of these flours decreased consumer appeal based on appearance. Nonetheless, these ingredients contain beneficial bioactive compounds such as carotenoids and polyphenols, which contribute additional health benefits (Pandi & Rizvi, 2009). Therefore, while wheat flour typically yields a neutral appearance, the use of coloured legumes and grains can enhance both the nutritional value and visual appeal of food products.

**3. Improving Nutrition and Economy through Composite Flours**

The food industry is continuously evolving to address emerging consumer demands by utilizing innovative technologies to develop healthier and more cost-effective products (Ververis et al., 2020). For instance, global sales in the snacking sector were projected to exceed $620 billion by 2021 (Statista, 2020). One effective strategy for reducing production costs while supporting domestic economies is the use of composite flours, blends of locally sourced crops such as legumes, tubers, and grains. These blends decrease reliance on imported wheat, lower production expenses, and contribute to enhancing food availability (Wang & Jian, 2022).

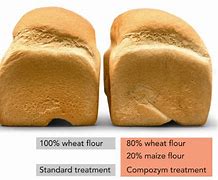
Reducing wheat imports also provides economic protection against volatile international market prices. In Nigeria, for example, policies are in place to substitute up to 40% of wheat flour with cassava flour to support local farmers and reduce gluten consumption (Ohimain, 2024). This transition promotes domestic agriculture, generates employment within the food production sector, and fosters sustainable farming practices (Adebayo et al., 2023). The inclusion of crops like cassava, soybeans, and pigeon peas enables farmers to increase their income while strengthening local food security (Stella et al., 2019).

Moreover, composite flours facilitate the production of healthier, affordable food products, which is particularly important in regions with limited access to nutritious diets (Hoehnel et al., 2022). Despite this potential, consumer acceptance remains a challenge, as many individuals are unfamiliar with the taste and texture of composite flour-based foods (Owusu et al., 2017). Wang and Jian (2022) observed hesitancy among consumers toward bread made from composite flours. Nonetheless, the rising demand for sustainable and plant-based foods is expected to drive increased adoption of composite flours in the future. By blending wheat with nutrient-dense ingredients, composite flours enable the development of specialty products such as high-protein, high-fiber, or gluten-free foods (Park & Kim, 2023). Their application enhances the nutritional profile, texture, and overall quality of food products, positioning composite flours as a promising innovation in today’s dynamic food market.

**4. Application of Composite Flours to Processed Foods**

**4.1 Snacks, Pasta, and Cakes**

For individuals with busy lifestyles, snacks provide a convenient source of energy without requiring a full meal. Many healthy snack options incorporate ingredients such as dried fruits, which are high in dietary fiber and aid digestion. Composite flours are increasingly utilized in the production of baked snacks, including croissants, pies, muffins, and cupcakes. These flours are formulated by blending wheat with legume and tuber flours to enhance protein, fiber, and vitamin content while maintaining desirable taste and texture attributes (Aliman, 2021). Table 1 and Figure 1 illustrate several examples of food products developed using composite flours.

**Fig. 1. Plain Flour and Composite flour Products**

**Source: Wikipedia.com**

**4.2 Use of Composite Flours in Baked Product**

Composite flours are increasingly utilized to enhance the nutritional profile of biscuits and cookies. The inclusion of flours such as oat, millet, or chickpea raises fiber and protein content, supporting improved digestion and blood sugar regulation (Virk et al., 2019). For example, Yusuf et al. (2016) reported that cookies made from composite flours of plantain, maize, and African yam bean exhibited higher levels of protein, fat, moisture, beta-carotene (a vitamin A precursor), vitamin C, and iron compared to traditional wheat flour cookies, which contained higher carbohydrate levels.

Composite flour-based cakes demonstrate improved nutritional value and texture. The incorporation of quinoa, sorghum, or almond flours enhances essential nutrients, including amino acids and vitamins, in wheat flour-based products (Peñalver et al., 2023). These composite flours also play a significant role in gluten-free baking. For instance, wheat flour is often blended with maize, rice, and buckwheat flours to achieve desired flavor and texture in gluten-free pies and tarts (Siddiqu et al., 2022). Chhotaray et al. (2021) found that cakes enriched with composite flours contained higher protein, fat, fiber, and ash content, along with reduced moisture and carbohydrate levels.

In pastries such as croissants, blending wheat flour with almond, oat, or spelt flours enhances flakiness, flavor complexity, and nutritional content (Ooms et al., 2016). During bread production, the addition of legume flours, including lentil and chickpea, improves both flavor and nutritional value; lentil flour notably increases essential mineral content (Bojňanská et al., 2012). Abu et al. (2021) demonstrated that combining potato, cassava, and soybean flours in bread formulations significantly enhanced nutritional quality. For individuals with diabetes, incorporating malted rice flour specifically a blend of 35% rice flour with 65% wheat flour improves dough rising, moisture retention, crust color, and lowers the glycemic index, making it a healthier alternative (Veluppillai et al., 2010).

Composite flours are also applied in noodle production. Combinations of water chestnut, colocasia, and sweet potato flours produce lower-gluten noodles suitable for individuals with celiac disease, offering improved texture, higher moisture content, and shorter cooking times (Baljeet et al., 2014). Additionally, Husniati and Anastasia (2013) found that incorporating fermented cassava flour enhanced noodle strength and overall quality.

**Table 1: Products Made from Composite Flours**

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| **Product Raw Materials/Composite Flour Reference**  Bread Wheat – fluted pumpkin seed flour Agu et al. (2010)  Doughnut Wheat – detoxified cassava flour Lugbe et al. (2009)  Cakes Wheat- African breadfruit flour Iheadiohanma et al. (2009)  Biscuits Wheat – *Colocasia esculenta* flour Iwe and Egwuekwe (2010)  Extruded snacks Cassava mash-desiccated coconut- Akinwotu et al. 2022  Cocoa powder  Cookies Wheat, millet flour and African yam bean Abioye *et al.,* 2018  Cookies Potato and wheat flour Jemziya et al., 2015 |

**4.3 Utilization of Composite Flours in Porridge**

Porridge is a popular morning meal because it is easy and quick to prepare (Afolabi et al., 2018). Porridge is prepared using grains like oats, maize, or sorghum. Conventional porridge may nevertheless lack vital nutrients like protein, fibre, and vitamins (Sadhu et al., 2017; Ronto et al., 2018). Mixing with composite flours, a blend of cereal or tuber flour and legumes can appreciably improve nutritional value. Blends make porridge higher in protein, fibre, and vitamins, and thus health improves, especially for children (Godswill, 2019; Emmanuel et al., 2019; Dendegh et al., 2021; Kumsa & Ararso, 2020).

**5. Impact of Storage on Quality of Composite Flour Product**

Compost flour products also need proper packaging to maintain their nutritional value, flavor, and shelf life. Packaging serves to protect the product from ambient temperatures, humidity, and oxygen, which drive chemical and physical transformations (Wang et al., 2018). The ingredients' composition in the flour and storage they receive significantly impact how long-lasting the product is.

**5.1 Determinants of Shelf Life and Quality**

The shelf life of composite flour products depends on both the inherent characteristics of the flour and the conditions under which they are stored. Internally, factors such as fat and moisture content greatly influence spoilage rates. Externally, the quality of packaging, along with temperature and humidity levels, critically affect how quickly these products deteriorate. For example, Shaviklo et al. (2015) showed that moisture or air infiltration into packaging can degrade the flavor and texture of extruded foods. Proper temperature management is vital, as exposure to extremes either too hot or too cold can lead to clumping, off-flavors, and texture problems (Iqbal & Fitzpatrick, 2006). Additionally, poor storage conditions may cause flour to absorb moisture, making it difficult to handle and reducing its functionality (Igbabul & Fitzpatrick, 2006; Forsido et al., 2021). Consequently, effective packaging combined with controlled storage environments is essential to maintain the freshness and quality of composite flour products.

**6. Packaging and Its Effect on Taste and Nutritional Quality**

Packaging and storage conditions play a crucial role not only in extending a product’s shelf life but also in preserving its flavor and aroma. Packaging that is weak or permeable can allow air to penetrate, leading to the loss of important flavor compounds like spices and natural aromas, which diminishes the product’s sensory appeal (Bhardwaj et al., 2021). Inadequate temperature control during storage can also affect texture, resulting in problems such as freezer burn in frozen items (Guiné, 2022). Moreover, exposure to excessive heat or moisture speeds up nutrient breakdown, which reduces the nutritional quality of the food (Bhardwaj et al., 2021). Therefore, selecting packaging materials that protect and maintain flavor, aroma, and texture is essential to ensure the product remains both nutritious and enjoyable throughout its shelf life (Barden & Decker, 2013).

**6.1 Shelf Life Extension through Moisture Management**

Removing moisture from packaging is crucial for maintaining the freshness of composite flour products. When water enters the package, it can lead to mold growth, spoilage, and loss of texture, causing sogginess. Akinwotu et al. (2022) demonstrated that both storage duration and the type of packaging material significantly affect moisture levels and fat degradation, measured by peroxide values, in cassava-based foods. Using moisture-resistant packaging is therefore vital to prevent these quality issues (Labuza et al., 1972; Kumari, 2024). Techniques like Accelerated Shelf Life Testing (ASLT), which mimic harsh storage conditions, help predict moisture impact on product quality and assist in selecting optimal packaging solutions (Calligaris et al., 2019). Choosing the right packaging ensures the product remains dry, nutritious, and stable over an extended shelf life.

**6.2 Composite Flour Product Packaging Material Types**

The choice of packaging material plays a crucial role in determining the shelf life and quality preservation of composite flour products. Different materials vary in their permeability to moisture and gases, which affects how well they protect the product. Commonly used materials such as polyethylene (PE) and polypropylene (PP) offer varying degrees of moisture resistance, with polyethylene being especially effective at blocking moisture, an important feature for flour packaging (Gupta et al., 2022).

There are also environmentally friendly alternatives like bioplastics made from plant-based sources, including polylactic acid (PLA) and starch-based films. While these sustainable options reduce environmental impact, they tend to allow higher moisture penetration, particularly in humid conditions, which can shorten the shelf life of products (Gupta et al., 2022). Therefore, selecting packaging must carefully consider the product’s sensitivity to moisture, intended storage environment, and desired shelf duration. With growing consumer awareness about environmental issues, the demand for packaging that balances food protection and eco-friendliness continues to rise. Food manufacturers are increasingly tasked with finding materials that not only safeguard food quality effectively but also minimize environmental harm (Janjarasskul et al., 2010, Arshad et al. 2025).

**7. Conclusion**

This review highlights that composite flours serve as a promising alternative to traditional wheat flour, addressing nutritional deficiencies and promoting more sustainable agricultural practices. By blending flours from legumes, millet, quinoa, and amaranth, these composites enhance the protein, fiber, vitamin, and antioxidant content of food products. The methods used to process these flours such as baking, roasting, or extrusion significantly influence the retention of these valuable nutrients. Moreover, proper storage and packaging are critical to preserving the freshness and nutritional quality of foods made from composite flours.

Emerging applications of composite flours have the potential to increase food diversity and improve food security, particularly in regions with limited access to high-quality grains. Continued research is essential to optimize flour blends and processing techniques, enabling broader use of composite flours across various food products.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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