**COMPOSITE FLOURS: APPLICATIONS, NUTRITIONAL BENEFITS, AND PROCESSING TECHNIQUES- A COMPREHENSIVE REVIEW**

**Abstract**

Composite flours, composed of different kinds of flour mixed together, are here understood as an emerging alternative to regular wheat flour. They are used to help rectify agricultural issues and improve nutrition. Composite flours consist of ingredients like grains, tubers, and enriched nutrients from millet, quinoa, amaranth, or legumes. The mixes help improve the amount of protein, fiber, vitamins, and antioxidants in food. The research also explores methods by which cooking procedures like baking, frying, roasting, or extrusion can modify the nutrient compositions of foods manufactured from such flours. The research focuses on how to retain important nutrients during processing. Further, the research discusses how storage, moisture control, and packaging affect the quality, flavor, and shelf life of such foods. Lastly, it discusses new trends in the use of composite flours, especially in areas that have limited access to quality grains and proteins, and shows how these blends can lead to improved overall food quality.

Key words: Composite flour, storage, frying, extrusion

**1. Introduction**

Composite flour is made by mixing different flours and is attracting interest as a replacement for wheat flour to manufacture other food commodities (Nyembwe et al., 2018; Emmanuel et al., 2019). These blends are usually mixtures of flours obtained from tubers, grains, legumes, and pseudocereals. The main objective is to enhance the nutritional value and functionality of food (Hasmadi et al., 2020). This procedure also reduces wheat reliance, which is exposed to climate change and the volatility of the global market (Awolu et al., 2017). Cassava, sweet potato, maize, and rice are staple foods. They are affordable and high in carbohydrates (Chandrasekara and Joseph, 2016) but are nutrient-deficient, resulting in malnutrition (Oyeyinka et al., 2020; Olamiti and Ramashia, 2024). Legumes and pseudocereals are added to enhance protein, fiber, and mineral content to make this better (Pakhare et al., 2018). The way foods are processed such as frying or baking has the ability to alter what they contain, so knowing how these types of processing affect the end product is crucial (Sruthy et al., 2023; Li et al., 2017). This review explores the benefits of using tubers and cereals in composite flours and examines how their nutritional value can be enhanced by incorporating nutrient-rich flours. It also detects how cooking processes and storage influence the nutrition, shelf life, and quality of products.

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

**2.1 Nutritional Benefits:**

The materials applied in composite flours (CF) directly impact the nutrition and functionality of food products. Legume and seed incorporation increases protein, fiber, and healthy fat content with greater flavor and texture (Sharma et al., 2013; Moraes et al., 2010). Soy flour, for example, incorporated into wheat bread increases its mineral content (Mandula et al., 2018). The composite flours contain approximately 15g of protein per 100g, compared to a regular wheat flour having 10g, which aids muscle repair (Oyeyinka et al., 2023). They have greater amounts of healthy fats approximately 2g per 100g than wheat at 1g, which helps in vitamin absorption by the body (Aslam et al., 2014). There is also greater content of fiber at 8g as opposed to 2g contained in wheat, which helps in digestion, weight regulation, and lowering the risk of type 2 diabetes (Adebayo et al., 2023).

Bello et al. (2019) confirmed that wheat blending with pigeon pea and raw plantain enhanced protein and fiber content, improving the nutritional value. The blends also help reduce the demand for grain imports (Omeire et al., 2014). Some anti-nutrients naturally occurring substances that interfere with nutrient absorption like hydrogen cyanide and oxalate were reduced in CF through proper processing (Bello et al., 2019). This means that understanding both the nutrients and the risks in flours of differing types is important to preparing the best mixtures.

**2.2 Bioactive and Antioxidant Properties**

Composite flours also deliver a perfect blend of nutrients that can deter hunger and malnutrition, especially among poor people (Pakhare et al., 2018). Composite flours also have a lower glycaemic index, which is helpful to people who have to control blood sugar levels, e.g., people with diabetes. CF are highly enriched with essential vitamins such as B-complex, A, and C, which stimulate immunity, metabolism, and fight oxidative stress (Rashwan et al., 2021).

Research indicates that fortification of CF can enhance its health effects. For instance, Akinwotu et al. (2024) demonstrated that supplementing cassava mash with coconut and cocoa increased its antioxidant and mineral content. Hoehnel et al. (2022) identified that pasta supplemented with CF was of superior protein quality compared to normal wheat pasta. Legumes in CF also contain special compounds like flavonoids, phenolic acids, and carotenoids, which have antioxidant and anti-inflammatory activities (Tang et al., 2015). They also improve flavor, texture, and shelf life of food when used in composite food preparation (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 finding more application in food manufacturing with the improvement of nutrition and the capacity to create a wider range of food products. Whether the composite flours will perform well when cooking or baking happens depends on what they are made of more importantly, their ratios of carbs, proteins, fats, water content, fiber, minerals, and added components like sugar substitutes (Awuchi, 2017; Awuchi & Echeta, 2019). These ingredients have a bearing on large characteristics like the volume of water that the flour can absorb, thickness, texture, and color. These are large characteristics because they dictate the flavor, appearance, and shape retention of the final product (Bello et al., 2019).

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

Water absorption is important as it dictates how well dough holds water when mixing and cooking (Godwill et al., 2019). The water absorption capacity of a flour mixture depends on the type of flour and its properties. Flours that have more fiber content like chickpea or legume flours will absorb more water compared to normal wheat flour (Source et al., 2019). For instance, adding chickpea flour to wheat flour increases the water absorption capacity due to higher protein and fiber content in chickpeas.

The level of water absorbed by the flour influences the consistency of the dough and the final product. When flour does not absorb sufficient water, the dough is stiff and hard, will not rise, and the final product is dense and rapidly becomes stale. When too much water is absorbed, the dough is sticky and deteriorates faster (Godwill et al., 2019). Chandra et al. (2015) determined that combinations of wheat, rice, green gram, and potato flour utilized made the biscuits tender and fresh for a longer period.

Viscosity is the test of how thin or thick a hot flour mixture is. Gelation is what happens as the mixture experiences gelation when heated and absorbed water (Godwill et al., 2019). These are properties that are applicable in foods like soups or sauces where consistency matters. Thick the paste is will vary based on the type of starch and how much two components of starch, amylose and amylopectin, it contains. More amylopectin-containing flours, rice or potato flour, create thicker pastes than wheat flour. Zhang et al. (2021), for example, showed rice flour to make thicker and stickier dough that is ideal to use in noodle making. Getachew and Admassu (2022) also found that mixing wheat with oat and moringa flours produced thicker dough, which is well-suited for healthy noodles.

Rheology is how dough deforms, flows, and works when it is being mixed and formed (Godwill et al., 2019). These traits determine how easy the dough is to work and how the final food will appear. Wheat gluten is something that plays a central role here, and the addition of other flours can make gluten more tender. However, that can be managed by adding other components like binding agents that can stabilize the dough.

In a study by Getachew and Admassu (2022), the incorporation of wheat with moringa and oat flour improved the quality of noodle dough. However, in another case, Adegoke et al. (2015) found that breadfruit flour addition to wheat dough changed its nature and compromised the quality of bread. This shows that knowledge on how flours interact when mixed is necessary for creating well-shaped products.

**(iv) Swelling Capacity**

Swelling capacity refers to the extent to which flour expands when mixed with water and heated (Iwe et al., 2016). Swelling capacity is largely determined by starch content, particularly by the type of starch molecules. High amylopectin flours swell higher. Salunkhe and Immanuel (2022) noted that the inclusion of rice, green gram, and potato flours increased swelling, but excess wheat flour decreased swelling. It influences how soft and moist a baked food will be.

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

The addition of the flours from the other wheat sources alters the flavor, texture, and appearance of food. Legumes like lentils and chickpeas give baked goods nutty or earthy flavor. Chickpea flour has a slightly sweet, nutty flavor, while lentil flour is stronger with an earthy taste. The tastes can be balanced by the use of foodstuffs like spices in meals or vanilla in sweets (Olamiti & Ramashia, 2024). The texture is also modified. Legume flours cause foods to become denser or slightly coarse. Without the right mix, products become dry or gritty. Bojnanska et al. (2021) found that using chickpea, lentil, and bean flour changed the texture of the dough and affected the overall quality of the bread. Other legumes impart a bitter or "beany" aftertaste. This can be balanced by mixing with less intensely flavored flours like rice or quinoa. Studies like Abu et al. (2021) have shown that balanced combinations of flour increase flavor and mouthfeel.

Color is another key attribute. Using flour made from yellow or orange foods like sweet potato or maize can change the color of baked products. Bibiana et al. (2014) found that using higher proportions of these flours lowered the appeal of bread in appearance. These ingredients, however, also contain health-promoting compounds like carotenoids and polyphenols, which provide other health benefits (Pandi & Rizvi, 2009). Therefore, whereas wheat flour offers an unseen look, the use of colored legumes and grains can provide nutrition as well as beauty.

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

The food industry is evolving to meet new consumer needs by leveraging technology to create healthful and lower-cost products (Ververis et al., 2020). For example, global snacking sales were expected to hit over $620 billion by 2021 (Statista, 2020). Another method of cutting down on costs and benefiting the domestic economies is via composite flours, which are blends of local crops like legumes, tubers, and grains. The blends reduce the level of imported wheat, conserve production costs, and aid in boosting food supply (Wang & Jian, 2022).

Less importation of wheat can also protect the economy of a country against unstable international prices. In Nigeria, for instance, there is a measure to replace as much as 40% of wheat flour with cassava flour to benefit farmers and reduce gluten consumption (Ohimain, 2024). The transition encourages domestic farming, gives jobs in food production, and enables sustainable agriculture (Adebayo et al., 2023). Incorporating crops like cassava, soybeans, and pigeon peas allows farmers to earn more income and ensures local food security (Stella et al., 2019).

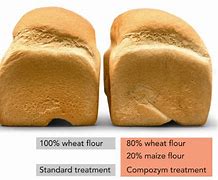
Composite flours also enable the production of healthier, less expensive foods. It is especially beneficial in areas where people lack access to nutritious meals (Hoehnel et al., 2022). However, it may be difficult to get people to accept new food products. People are usually not familiar with what composite flour foods taste and have a texture like (Owusu et al., 2017). Wang and Jian (2022) further found that people are generally hesitant to eat bread made from composite flour. However, the demand for sustainable and plant-based foods is increasing, which will likely increase the use of composite flours in the future.

With the blending of wheat with nutritious ingredients, such composite flours facilitate the production of specialty food items e.g., high protein, high fibre, or gluten-free foods (Park & Kim, 2023). With their application, they can increase the nutritional content, texture, and quality of foods, and hence composite flours are a new player in the current dynamic food market.

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

**4.1 Snacks, Pasta, and Cakes**

For those who are always on the go, snacks offer an easy and convenient way of achieving energy without needing a meal. Most healthy snacks contain ingredients like dried fruits, which are rich in fiber and help digest foods. Composite flours also broadly extend to the making of baked snacks like croissants, pies, muffins, and cupcakes. These flours are created through blending wheat with legume and tuber flours in order to add more protein, fibre, and vitamins without an impact on good taste or texture (Aliman, 2021). Table 1 and Figure 1 show some examples of the food that can be created with the use of 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 also used to enhance biscuits and cookies. Incorporating flours such as oat, millet, or chickpea increases the product's fiber and protein content, which supports better digestion and helps regulate blood sugar levels (Virk et al., 2019). For example, Yusuf et al. (2016) studied cookies made from composite plantain, maize, and African yam bean flours. These cookies had more protein, fat, water content, beta-carotene (vitamin A precursor), vitamin C, and iron than regular wheat flour cookies that had more carbohydrates.

Composite flour cakes are healthier and have better texture. The incorporation of flours like quinoa, sorghum, or almond improves the amount of essential nutrients like amino acids and vitamins in wheat flour (Peñalver et al., 2023). These flours are also used in gluten-free baking. For the production of gluten-free pies and tarts, wheat flour is occasionally mixed with maize, rice, and buckwheat flours to preserve the desired flavour and texture (Siddiqu et al., 2022). According to Chhotaray et al. (2021), the composite flour-enriched cakes had higher levels of protein, fat, fibre, and ash, and less moisture and carbohydrates.

Composite flours can also be used to enrich croissants and similar pastries. When the wheat flour is combined with almond, oat, or spelt flours, it contributes the flakiness and more flavors along with the enhanced nutrition (Ooms et al., 2016). During the production of bread, legume flours such as lentil or chickpea add flavor and nutritional enrichment. Lentil flour, for instance, adds essential minerals (Bojňanská et al., 2012). Abu et al. (2021) proved in a study that the combination of potato, cassava, and soybean flours into bread increased its nutrition. For diabetics, the use of malted rice flour in bread especially in the form of 35% rice flour combined with 65% wheat flour enhances dough rising, moisture and crust colour, and lowers the glycaemic index, therefore the healthier option (Veluppillai et al., 2010).

Composite flours now appear in foods like noodles. Water chestnut, colocasia, and sweet potato flour combinations were employed to produce lower-gluten noodles that would be suitable for individuals with celiac disease. The blends provide texture, contain more water, and are shorter cooking times (Baljeet et al., 2014). Husniati and Anastasia (2013) found that fermented cassava flour addition to noodles improved their strength and quality.

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

|  |
| --- |
| **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**

Both the nature of the flour used and external factors affect how long composite flour products stay fresh. Internally, fat and moisture content cause spoilage. Externally, package quality, temperature, and humidity can speed up or slow down this. For example, Shaviklo et al. (2015) proved that moisture or air penetration into packages ruins the flavour and texture of extruded products. Temperature is especially crucial, if too high or low, it leads to clumping, off taste, or texture issues (Iqbal & Fitzpatrick, 2006). The unsatisfactory storage conditions also caused the flour to absorb water, making it harder to store or use, according to Igbabul and Fitzpatrick (2006). Proper packaging and storage conditions are very important in maintaining products fresh.

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

The way in which something is packaged and stored affects not only how long something lasts, but also what it tastes and smells. If the packaging is too weak, air seeps in and causes vital flavour compounds like spices or natural aromas to become ineffective (Bhardwaj et al., 2021). Foods left at the wrong temperatures can also become texture-less, like frozen food, and freeze burn (Guiné, 2022). Along with this, over-heat or moisture storage could result in quicker degradation of the nutrients, lowering the dietary benefits of the food (Bhardwaj et al., 2021). To ensure the product nutritious as well as flavoursome, one must use a packaging material that protects flavour, aroma, and texture (Barden & Decker, 2013).

**6.1 Shelf Life Extension through Moisture Management**

Elimination of moisture from packaging is essential in keeping composite flour products fresh. Upon entry of water into the package, it will cause mould, spoilage, and sogginess. Akinwolu et al. (2022) found that storage time and packaging material influenced moisture content and fat spoilage (indicated by peroxide values) in cassava foods. Moisture-proof packaging is central to preventing such occurrences (Labuza et al., 1972). Accelerated Shelf Life Testing (ASLT) that simulates severe storage conditions can predict how moisture will affect quality and guide the choice of better packaging (Calligaris et al., 2019). Proper packaging selection makes the product dry, nutritious, and shelf-stable for an extended duration.

**6.2 Composite Flour Product Packaging Material Types**

The packaging material used contributes significantly to how long composite flour products stay fresh and how nicely they preserve their quality. Different packaging materials possess different amounts of moisture and gas permeability, depending on how much protection they are able to give to the product. Polyethylene (PE) and polypropylene (PP) materials are used since they are moisture-resistant to different degrees. Polyethylene is particularly apt in excluding moisture, which can be useful in products like flour (Gupta et al., 2022).

Environmental-friendly options also exist, such as bioplastic packaging possibilities based on plants like polylactic acid (PLA) or starch films. Being more eco-friendly, however, these possibilities will allow for higher moisture penetration, especially in humid environments, which reduces the product's shelf life (Gupta et al., 2022). Because of this, there is a need to choose packaging aligned with the product's water sensitivity, where it will be stored, and for how long it should endure.

As more people get concerned about the environment, demand for packaging that is efficient and eco-friendly is on the rise. Food companies now need to look for materials that are effective in safeguarding food but are also greener for the planet (Janjarasskul et al., 2010).

**7. Conclusion**

This article shows that composite flours are a good substitute for wheat flour. They address nutrition problems and ensure more sustainable agriculture. By mixing flours of legumes, millet, quinoa, and amaranth, these mixes increase the content of protein, fibre, vitamins, and antioxidants in food. Whether the composite flours are treated by baking, roasting, or extrusion also matters in determining how much of the nutrients are retained. Additionally, the storage and packaging of the foods also play an essential role in maintaining them fresh and as healthy as can be.

New uses of composite flours promise to improve both food variety and security, especially in areas where availability of good-quality grains is low. Further research in the future is required to improve flour mixtures and food processing techniques so such flours can be suitable for use in even more foods.

**References**

Adebayo, T. K., Daramola, A. S., Abdulraheem, I. A., & Jimoh, K. A. (2023). Effect of inclusion of velvet bean on the proximate composition and functional properties of the wheat-plantain flour blends. *World Journal of Advanced Research & Reviews, 20*(3), 562-573.

Afolabi, F., Juwon Arotupin, D., Adewunmi Alabi, M., Temitope Ojo, O., & Olowokere, T. (2018). Improving nutritive value of fermented cereal porridge ‘Ogi’ by fortifying with Bambara nut. *Croatian Journal of Food Science and Technology, 10*(1), 51-57.

Agu, H. O., Ukonze, J. A., & Paul, K. A. (2010). Quality characteristics of bread made from wheat and fluted pumpkin seed flours. *Nigerian Food Journal, 28*(1), 188–198.

Akande, O., Nakimbugwe, D., & Mukisa, I. (2017). Optimization of extrusion conditions for the production of instant grain amaranth-based porridge flour. *Food Science and Nutrition, 5*, 1205–1214.

Alrahaife, A. J., & Abu-Alruz, K. (2023). Effects of incorporation of lupin flour on the quality attributes of beef burger. *Online Journal of Animal Feed Research, 13*(5), 328-339.

Aslam, H. K. W., Raheem, M. I. U., Ramzan, R., Shakeel, A., Shoaib, M., & Sakandar, H. A. (2014). Utilisation of mango waste material (peel, kernel) to enhance dietary fibre content and antioxidant properties of biscuit. *Journal of Global Innovations in Agricultural and Social Sciences, 2*(2), 76-81.

Baljeet, S. Y., Ritika, B. Y., Manisha, K., & Bhupender, S. K. (2014). Studies on suitability of wheat flour blends with sweet potato, colocasia, and water chestnut flours for noodle making. *LWT - Food Science and Technology, 57*(1), 352–358.

Barden, L., & Decker, E. (2013). Lipid oxidation in low-moisture food: A review. *Critical Reviews in Food Science and Nutrition, 56*(15), 2467-2482.

Bello, F. A., Oyeniyi, A. O., & George, I. O. (2019). Chemical and functional properties of wheat, pigeon pea, and plantain composite flour. European Journal of Food Science and Technology, 7(4), 1–8.

Bojňanská, T., Frančáková, H., Líšková, M., & Tokár, M. (2012). Legumes – the alternative raw materials for bread production. *Journal of Microbiology, Biotechnology and Food Sciences, 1*, 876-886.

Calligaris, S., Manzocco, L., Anese, M., & Nicoli, M. C. (2019). Accelerated shelf life testing. In *Food Quality and Shelf Life* (pp. 359-392). Academic Press.

Chen, Y.-T., Kao, W.-T., & Lin, K.-W. (2008). Effects of pH on the total phenolic compound, antioxidative ability and the stability of dioscorin of various yam cultivars. *Food Chemistry, 107*(1), 250–257.

Ciudad, M., Fernández, V., Cuadrado, C., et al. (2020). Novel gluten-free formulations from lentil flours and nutritional yeast: Evaluation of extrusion effect on phytochemicals and non-nutritional factors. *Food Chemistry, 315*, 126175. https://doi.org/10.1016/j.foodchem.2020.126175

Dendegh, T. A., Yelmi, B. M., & Dendegh, R. A. (2021). Evaluation of stiff porridge (Ruam Nahan) produced from composite flour blends of pearl millet (*Pennisetum glaucum*) and African yam bean (*Sphenostylis stenocarpa*). *Asian Food Science Journal, 20*(9), 63-77.

Elizalde, A., Portilla, Y., & Chaparro, D. (2009). Factores antinutricionales en semillas. *Facultad de Ciencias Agropecuarias, 7*(1), 54.

Emmanuel, K. O., Michael, A. I., Olajide, P. S., & Bakare, H. A. (2019). Quality attributes and storage stability of bread from wheat–tigernut composite flour. *Journal of Culinary Science & Technology, 17*(1), 1-14.

FAO. (2021). *FAOSTAT data*. Retrieved March 26, 2021, from <http://www.fao.org/faostat/en/#data>

FAO. (2023). Production: Crops and livestock products. *FAOSTAT*. Rome. Retrieved December 2023, from https://www.fao.org/faostat/en/#data/QCL

FAOSTAT. (2013). [*http://faostat3.fao.org*](http://faostat3.fao.org).

Godswill, A. A. (2019). Proximate composition and functional properties of different grain flour composites for industrial applications. *International Journal of Food Science, 2*(1), 43-64.

Govender, L., Siwela, M., & Denhere, S. (2022). The effect of adding Bambara groundnut (*Vigna subterranea*) on the physical quality, nutritional composition, and consumer acceptability of a provitamin A-biofortified maize complementary instant porridge. *Journal of Diversity, 14*, 1088.

Guiné, R. P. F. (2022). Textural properties of bakery products: A review of instrumental and sensory evaluation studies. *Applied Sciences, 12*(17), 8628.

Guo, F., Danielski, R., Santhiravel, S., & Shahidi, F. (2024). Unlocking the nutraceutical potential of legumes and their by-products: Paving the way for the circular economy in the agri-food industry. *Antioxidants (Basel), 13*(6), 636. https://doi.org/10.3390/antiox13060636

Guo, H., Hao, Y., Richel, A., Everaert, N., Chen, Y., Liu, M., Yang, X., & Ren, G. (2020). Antihypertensive effect of quinoa protein under simulated gastrointestinal digestion and peptide characterization. *Journal of the Science of Food and Agriculture, 100*(15), 5569–5576.

Gupta, R. K., Gangoliya, S. S., & Singh, N. K. (2015). Reduction of phytic acid and enhancement of bioavailable micronutrients in food grains. *Journal of Food Science and Technology, 52*, 676–684.

Gupta, V., Biswas, D., & Roy, S. (2022). A comprehensive review of biodegradable polymer-based films and coatings and their food packaging applications. *Materials, 15*(17), 5899.

Hasmadi, M., Noorfarahzilah, M., Noraidah, H., Zainol, M. K., & Jahurul, M. H. A. (2020). Functional properties of composite flour: A review. *Food Research, 4*(6), 1820-1831.

Hoehnel, A., Bez, J., Petersen, I. L., Amarowicz, R., Juśkiewicz, J., Zannini, E., & Arendt, E. K. (2022). Combining high-protein ingredients from pseudocereals and legumes for the development of fresh high-protein hybrid pasta: Enhanced nutritional profile. *Journal of the Science of Food and Agriculture, 102*, 5000–5010.

Husniati, & Anastasia, F. D. (2013). Effect of the addition of glucomannan to the quality of composite noodle prepared from wheat and fermented cassava flours. *Journal of Basic and Applied Science Resources, 3*(1), 1-4.

Iqbal, T., & Fitzpatrick, J. J. (2006). Effect of storage conditions on the wall friction characteristics of three food powders. *Journal of Food Engineering, 72*(3), 273-280.

Iwe, M. O., & Egwuekwe, E. I. (2010). Production and evaluation of cookies from Xanthosoma sagittifolium and Colocasia esculenta blends. *Nigerian Food Journal, 23*(1), 145–153.

Janjarasskul, T., & Krochta, J. M. (2010). Edible packaging materials. *Annual Review of Food Science and Technology, 1*, 415–448.

Ji, X., Rivers, L., Zielinski, Z., et al. (2012). Quantitative analysis of phenolic components and glycoalkaloids from 20 potato clones and in vitro evaluation of antioxidant, cholesterol uptake, and neuroprotective activities. *Food Chemistry, 133*(4), 1177–1187.

Kim, H. K., Kim, M. J., Cho, H. Y., Kim, E.-K., & Shin, D. H. (2006). Antioxidative and anti-diabetic effects of amaranth (*Amaranthus esculantus*) in streptozotocin-induced diabetic rats. *Cell Biochemistry and Function, 24*(3), 195–199.

Kim, J. J., Kim, C. W., Park, D. S., et al. (2008). Effects of sweet potato fractions on alcoholic hangover and gastric ulcer. *Laboratory Animal Research, 24*, 209–216.

Kim, M., Chung, K. S., Hwang, S. J., Yoon, Y. S., Jang, Y. P., Lee, J. K., & Lee, K. T. (2020). Protective effect of *Cicer arietinum* L. (Chickpea) ethanol extract in the dextran sulfate sodium-induced mouse model of ulcerative colitis. *Nutrients, 12*, 456.

Kumsa, N. A., & Ararso, L. J. (2020). Development and evaluation of complementary porridge blends from germinated maize, soybean, and sweet potato. *Food Science & Nutrition Technology, 5*(6), 000242.

Liu, Y., Ragaee, S., Marcone, M. F., & Abdel-Aal, E.-S. M. (2020). Effect of different cooking methods and heating solutions on nutritionally-important starch fractions and flatus oligosaccharides in selected pulses. *Cereal Chemistry, 97*, 1216–1226.

Lozano-Castellón, J., Rinaldi de Alvarenga, J. F., Vallverdú-Queralt, A., & Lamuela-Raventós, R. M. (2022). Cooking with extra-virgin olive oil: A mixture of food components to prevent oxidation and degradation. *Trends in Food Science & Technology, 123*, 28-36.

Lugbe, P. B., Mepba, H. D., & Sokari, T. G. (2009). Physicochemical properties of fungal detoxified cassava mash and sensory attributes of wheat-detoxified cassava composite doughnuts. *Nigerian Food Journal, 27*(1), 36–47.

Moraes, E. A., Dantas, M. I. de S., Morais, D. de C., da Silva, C. O., de Castro, F. A. F., Martino, H. S. D., Ribeiro, S. M. R. (2010). Sensory evaluation and nutritional value of cakes prepared with whole flaxseed flour. *Ciencia e Tecnologia de Alimentos, 30*(4), 974-979.

Moriyasu, Y., Fukumoto, C., Wada, M., Yano, E., Murase, H., Mizuno, M., Zaima, N., & Moriyama, T. (2021). Validation of antiobesity effects of black soybean seed coat powder suitable as a food material: Comparisons with conventional yellow soybean seed coat powder. *Foods, 10*, 841.

Nyembwe, P. M., de Kock, H. L., & Taylor, J. R. N. (2018). Potential of defatted marama flour-cassava starch composites to produce functional gluten-free bread-type dough. *LWT, 92*, 429-434.

Oduro-Obeng, H., & Plahar, W. A. (2017). Development, quality evaluation and estimated contribution of composite flour snack foods to nutrient requirements of young children aged 2 to 6 years. *Council for Scientific and Industrial Research Ghana*. <https://csirspace.foodresearchgh.site/handle/123456789/1307>. Accessed August 22, 2024.

Oğuz, A., & Sayaslan, A. (2019). Antioxidant properties of roasted whole-grain, oilseed, and nut snacks and effect of roasting process on these properties. *Akademik Gıda, 17*(2), 149-156.

Ohimain, E. I. (2014). The prospects and challenges of composite flour for bread production in Nigeria. *Global Journal of Human-Social Science: H Interdisciplinary*, 14(3), 1–10.

Olamiti, G., & Ramashia, S. E. (2024). Impact of composite flour on nutritional, bioactive, and sensory characteristics of pastry foods: A review. *Nutritional Food Science, 12*(3).

Omeire, G. C., Umeji, O. F., & Obasi, N. E. (2014). Acceptability of noodles produced from blends of wheat, acha, and soybean composite flours. *Nigerian Food Journal, 32*(1), 31–37.

Ooms, N., Pareyt, B., Brijs, K., & Delcour, J. A. (2016). Ingredient functionality in multilayered dough-margarine systems and the resultant pastry products: A review. *Critical Reviews in Food Science & Nutrition, 56*(13), 2101-2114.

Oyeyinka, S. A., & Bassey, I. A. V. (2023). Composition, functionality, and baking quality of flour from four brands of wheat flour. *Journal of Culinary Science & Technology*, 1-21.

Owusu, V., Owusu-Sekyere, E., Donkor, E., Darkwaah, N. A. & Adomako-Boateng Jr, D. (2017). Consumer perceptions and willingness to pay for cassava-wheat composite bread in Ghana: a hedonic pricing approach. *J. Agribusiness Dev. Emerging Econ.* **7**, 115–134

Pakhare, K. N., Dagadkhair, A. C., & Udachan, I. S. (2018). Enhancement of nutritional and functional characteristics of noodles by fortification with protein and fiber: A review. *Journal of Pharmacognosy and Phytochemistry, 7*(1), 351-357.

Panda, V., & Sonkamble, M. (2011). Anti-ulcer activity of *Ipomoea batatas* tubers (sweet potato). *Functional Foods in Health and Disease, 2*(3), 48–61.

Park, J., & Kim, H. S. (2023). Rice-based gluten-free foods and technologies: A review. *Foods, 12*(22), 4110.

Peñalver, R., Ros, G., & Nieto, G. (2023). Development of functional gluten-free sourdough bread with pseudocereals and enriched with Moringa oleifera. *Foods, 12*(21), 3920.

Pico, J., Pismag, R. Y., Laudouze, M., et al. (2020). Systematic evaluation of the Folin-Ciocalteu and Fast Blue BB reactions during the analysis of total phenolics in legumes, nuts, and plant seeds. *Food Function, 11*(11), 9868–9880.

Pico, J., Xu, K., Guo, M. (2019). Manufacturing the ultimate green banana flour: Impact of drying and extrusion on phenolic profile and starch bioaccessibility. *Food Chemistry, 297*, 124990.

Qi, M., Zhang, G., Ren, Z., et al. (2021). Impact of extrusion temperature on in vitro digestibility and pasting properties of pea flour. *Plant Foods for Human Nutrition, 76*(1), 26–30.

Ververis, E., Ackerl, R., Azollini, D., Colombo, P. A., da Sesmaisons, A., Dumas, C., Fernandez-Dumont, A., Ferreira da Costa, L., Germini, A., Goumperis, T., Kouloura, E., Matijevic, L., Precup, G., Roldan-Torres, R., Rossi, A., Svejstil, R., Turla, E., & Gelbmann, W. (2020). Novel foods in the European Union: Scientific requirements and challenges of the risk assessment process by the European Food Safety Authority. Food Research International, 137, 109515.

Statista. (2017). Value of global nuts and seeds market 2017-2024. Statista. <https://www.statista.com/statistics/1064315/nuts-and-seeds-market-value-worldwide/>

Stella, G., Coli, R., Maurizi, A., Famiani, F., Castellini, C., Pauselli, M., Tosti, G., Menconi, M. (2019). Towards a national food sovereignty plan: application of a new Decision Support System for food planning and governance. *Land Use Pol.* 89, 104216

Rashwan, A. K., Yones, H. A., Karim, N., Taha, E. M., & Chen, W. (2021). Potential processing technologies for developing sorghum-based food products: An update and comprehensive review. *Trends in Food Science & Technology, 110*, 168-182.

Rastogi, N. K. (2012). Recent trends and developments in infrared heating in food processing. *Critical Reviews in Food Science & Nutrition, 52*, 737-760.

Ronto, R., Wu, J. H., & Singh, G. M. (2018). The global nutrition transition: Trends, disease burdens, and policy interventions. *Public Health Nutrition, 21*(12), 2267-2270.

Sahasrabudhe, S., Rodriguez-Martinez, V., O'Meara, M., & Farkas, B. (2017). Density, viscosity, and surface tension of five vegetable oils at elevated temperatures: Measurement and modeling. *International Journal of Food Properties, 1-17*.

Sánchez-Chino, X. M., Jiménez Martínez, C., & León-Espinosa, E. B. (2019). Protective effect of chickpea protein hydrolysates on colon carcinogenesis associated with a hypercaloric diet. *Journal of the American College of Nutrition, 38*(2), 162–170.

Sharma, C., Punia, D., & Khetarpaul, N. (2013). Sensory characteristics, proximate composition, dietary fiber content, and storage stability of barley, wheat, and chickpea composite flour biscuits. *British Food Journal, 115*(6), 876–883.

Shaviklo, A. R., Azaribeh, M., Moradi, Y., & Zangeneh, P. (2015). Formula optimization and storage stability of extruded puffed corn-shrimp snacks. *LWT - Food Science and Technology, 63*(1), 307-314.

Shi, L., Arntfield, S. D., & Nickerson, M. (2018). Changes in levels of phytic acid, lectins, and oxalates during soaking and cooking of Canadian pulses. *Food Research International, 107*, 660–668.

Shih, M.-C., Kuo, C.-C., & Chiang, W. (2009). Effects of drying and extrusion on colour, chemical composition, antioxidant activities and mitogenic response of spleen lymphocytes of sweet potatoes. *Food Chemistry, 117*(1), 114–121.

Siddiqui, S. A., Zannou, O., & Karim, I. (2022). Avoiding food neophobia and increasing consumer acceptance of new food trends—a decade of research. *Foods, 14*(16), 10391.

Singh, R. (2021). Effects of particle size distribution and extrusion processing parameters on the techno-functional properties of soybean meal. *Frontiers in Neuroscience*. University of Manitoba.

Sonibare, M. A., & Abegunde, R. B. (2012). In vitro antimicrobial and antioxidant analysis of *Dioscorea dumetorum* (Kunth) Pax and *Dioscorea hirtiflora* (Linn.) and their bioactive metabolites from Nigeria. *Journal of Applied Biosciences, 51*, 3583–3590.

Sruthy, G. N., Sandhya, K. R., Kumkum, R., Mythri, C. R., & Sharma, M. (2022). Thermal processing technologies for food. In *Current Developments in Biotechnology and Bioengineering: Advances in Food Engineering* (pp. 1-38).

Sunil, Chauhan, N., Singh, B. R., Chandra, S., Samsher, & Sengar, R. S. (2021). Evaluation of functional properties of composite flour. Chemical Engineering, 2(4), 73–76.

Li, M., Ma, M., Zhu, K. X., Guo, X. N., & Zhou, H. M. (2017). Critical conditions accelerating the deterioration of fresh noodles: A study on temperature, pH, water content, and water activity. *Journal of Food Processing and Preservation, 41*(4), e13173.

Tang, Y., Li, X., Zhang, B., Chen, P. X., Liu, R., & Tsao, R. (2015). Characterization of phenolics, betanins, and antioxidant activities in seeds of three *Chenopodium quinoa* genotypes. *Food Chemistry, 166*, 380-388.

Taylor, J. R. N., & Taylor, J. (2007). Proteins from sorghum and millets. In S. Nadathur, J. P. D. Wanasundara, & L. Scanlin (Eds.), *Sustainable protein sources* (pp. 79–104). San Diego, CA: Academic Press, Elsevier Inc.

Tharise, N., Julianti, E., & Nurminah, M. (2014). Evaluation of physico-chemical and functional properties of composite flour from cassava, rice, potato, soybean, and xanthan gum as an alternative to wheat flour. International Food Research Journal, 21(4), 1641–1649.

Tortoe, C., Akonor, P., Hagan, L., Kanton, R., Asungre, P., & Ansoba, E. (2019). Assessing the suitability of flours from five pearl millet (*Pennisetum americanum*) varieties for bread production. *Food Research Journal, 26*(1), 329-336.

Veluppillai, S., Nithyanantharajah, K., Vasantharuba, S., Balakumar, S., & Arasaratnam, V. (2010). Optimization of bread preparation from wheat flour and malted rice flour. *Rice Science, 17*(1), 51-59.

Vikram, N., Katiyar, S. K., Singh, C. B., Husain, R., & Gangwar, L. K. (2020). A review on anti-nutritional factors. International Journal of Current Microbiology and Applied Sciences, 9(5), 1128-1137.

Virk, A., Kaur, M., Thakur, P., Chauhan, D., & Rizvi, Q. (2019). Development and nutritional evaluation of multigrain gluten-free cookies and pasta products. *Current Research in Nutrition and Food Science Journal, 7*(3), 842-853.

Wang, J., Gardner, D. J., Stark, N. M., Bousfield, D. W., Tajvidi, M., & Cai, Z. (2018). Moisture and oxygen barrier properties of cellulose nanomaterial-based films. *ACS Sustainable Chemistry & Engineering, 6*(1), 49-70.

Wang, J., Li, A., Hu, J., Zhang, B., Liu, J., Zhang, Y., & Wang, S. (2022). Effect of frying process on nutritional property, physicochemical quality, and in vitro digestibility of commercial instant noodles. *Frontiers in Nutrition, 9*, 823432.

Zhang, H., Chen, G., Liu, M., et al. (2020). Effects of multi-frequency ultrasound on physicochemical properties, structural characteristics of gluten protein and the quality of noodle. *Ultrasonics Sonochemistry, 67*, 105135.

Zhu, Y., & Sang, S. (2017). Phytochemicals in whole grain wheat and their health-promoting effects. *Molecular Nutrition & Food Research, 61*, 1600852.

Manjula K, Jhansi D, Sudha S. (2018). Effect of Composite Flour on Quality and Nutritional Properties of Bread, International Journal of Life Sciences Research 6 (3): 364-367.

Goszkiewicz, A., Kochanska, E., & Korczak, K. (2020). Influence of microwave treatment on quality parameters of snack food. Impact Issues, Acta Innovations, 2020(36), 64–80.

Abioye V.F, Olatunde S.J, and Elias G. (2018). “Quality attributes of cookies produced from composite flours of wheat, germinated finger millet flour and African yam bean”. *International Journal of Research- Granthaalayah*, 6(11), 172-183.

Awuchi, C. G. (2017). Sugar alcohols: Chemistry, production, health concerns, and nutritional importance of mannitol, sorbitol, xylitol, and erythritol. International Journal of Advanced Academic Research (IJAAR), 3(2), 31-66.

Awuchi, C. G., Owuamanam, C. I., Ogueke, C. C., & Igwe, V. S. (2019). Evaluation of patulin levels and impacts on the physical characteristics of grains. International Journal of Advanced Academic Research, 5(4), 10-25.

Stone, A. K., Nosworthy, M. G., Chiremba, C., House, J. D., & Nickerson, M. T. (2019). A comparative study of the functionality and protein quality of a variety of legume and cereal flours. Comprehensive Reviews in Food Science and Food Safety, 18(6), 1714-1731.

Chandra, S., Singh, S., & Kumari, D. (2015). Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. Journal of Food Science and Technology, 52(6), 3681-3688.

Zhang, Y., Dong, J., Deng, C., Qian, Y., Zhou, Y., Wang, N. F., & Zhang, Q. (2021). Effect of glutinous rice flour supplementation on the properties of wheat flour and salted noodles. Journal of Food Processing and Preservation, 45(10), e15856. <https://doi.org/10.1111/jfpp.15856>

Getachew, M., & Admassu, H. (2022). Evaluation of functional and rheological properties of the composite flour from oat, wheat, and moringa tree leaves. Cogent Food & Agriculture, 8(1). <https://doi.org/10.1080/23311932.2022.2120009>

Prieto-Vázquez Del Mercado, P., Mojica, L., & Morales-Hernández, N. (2022). Protein ingredients in bread: Technological, textural, and health implications. Foods, 11(16), 2399. <https://doi.org/10.3390/foods11162399>

Bibiana, I., Grace, N., & Julius, A. (2014). Quality evaluation of composite bread produced from wheat, maize, and orange fleshed sweet potato flours. American Journal of Food Science and Technology, 2(4), 109-115.

Bojňanská, T., Musilová, J., & Vollmannová, A. (2021). Effects of adding legume flours on the rheological and breadmaking properties of dough. Foods, 10(5), 1087. <https://doi.org/10.3390/foods10051087>

Pandey, K. B., & Rizvi, S. I. (2009). Plant polyphenols as dietary antioxidants in human health and disease. Oxidative Medicine and Cellular Longevity, 2(5), 270-278. https://doi.org/10.4161/oxim.2.5.9498

Salunke, S., & Immanuel, G. (2022). Comparative evaluation of functional properties of composite flours made from amaranth, rice, and raw banana. Emerging Life Sciences Research, 8(2), 162-167.