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Nutritional properties of composite flours from unripe plantain (*Musa paradisiaca*) and bean pod (*Brachystegia eurycoma*)

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This study evaluated the nutritional composition and pasting properties of composite flours formulated from unripe plantain (*Musa paradisiaca*) and bean pod (*Brachystegia eurycoma*). Five flour blends were prepared in varying ratios: 100% unripe plantain flour (URPF), 100% bean pod flour (BPF), and three composite blends—URPF:BPF at 96:4, 92:8, and 88:12, respectively. Proximate analysis showed no significant differences ($p<0.05$) among samples in protein, ash, and carbohydrate content. Moisture content ranged from 5.50% to 7.77%, with 100% URPF having the highest value. The food energy content was highest in 100% BPF (381.58 kcal) and lowest in 100% URPF (363.42 kcal), with the composite samples showing intermediate, statistically similar values. Pasting analysis revealed that 100% BPF exhibited the highest values in most pasting parameters, except for setback viscosity and pasting temperature, which peaked in the 88% URPF:12% BPF and 96% URPF:4% BPF blends, respectively. Increasing levels of bean pod flour improved the setback viscosity and final viscosity, suggesting enhanced paste stability and reduced retrogradation. These findings highlight the potential of incorporating *B. eurycoma* into unripe plantain flour for producing nutrient-enriched, functional flours suitable for industrial applications and dietary management, particularly in regions facing food insecurity.

Keywords: Unripe plantain flour, bean pod (*Brachystegia eurycoma*), proximate composition, pasting properties, composite flour blends, functional food, dietary fiber.

INTRODUCTION

Plantain (*Musa paradisiaca*) is a major starchy staple and commercial crop in West and Central Africa, where approximately 50% of global production occurs (Umoh *et al.,* 2024). It is extensively cultivated in the Eastern and Southern regions of Nigeria, serving as both a food and cash crop. Rich in starch and essential minerals, particularly potassium; plantain is a significant source of carbohydrates, while being relatively low in protein and fat. It plays a vital role in the diets of both humans and livestock.

At the household level, plantain is valued for its high nutritional content, especially its abundance of vitamin A (Idumah *et al.,* 2016). It is consumed in various forms: raw, fried, boiled, roasted, or processed into flour. Unripe green plantains, when dried and milled, yield flour that is useful for diverse food applications, including weaning foods (Idumah *et al.,* 2016; Adeniji *et al.,* 2007). According to the Food and Agriculture Organization (FAO, 2014), Nigeria produces over 2.11 million metric tonnes of plantains annually, ranking among the world's leading producers. As a staple food, plantain contributes significantly to food security and rural income generation.

Plantain is both versatile and nutritious, widely consumed in ripe and unripe forms. Its nutritional profile is comparable to that of yam and potato. In Nigeria, it is prepared as snacks (e.g., chips), made into plantain-based amala, or traditional dishes like *dodo ikire* (Umoh *et al.,* 2024). Unripe and ripe plantains can be processed into

Figure 1. Unripe plantain (*Musa paradisiaca)* fingers (UPF). **Source:** Abiodun-Solanke and Falade, 2010.

flour, which is used to prepare *amala*, a low-glycemic gruel recommended for diabetic patients. Plantains also contain beneficial compounds such as phenolics, carotenoids, and dietary fiber (Baskar *et al.,* 2011), and their antioxidant properties are largely attributed to catecholamines (Vu *et al.,* 2018).

Beyond their edible pulp, plantain peels have long been used in traditional medicine across cultures (Imam and Akter, 2011). The plant is also important for smallholder farmers due to its adaptability and compatibility with other crops. Globally, plantain ranks as the fourth most significant food commodity after rice, wheat, and maize (FAOSTAT, 2009).

A nutritional study by Ogidi *et al.* (2017) across thirteen plantain cultivars found the peel's moisture content ranged from 78.74% to 87.33%, ash content from 0.87% to 2.38%, protein from 1.67% to 4.2%, lipid from 0.84% to 2.24%, fiber from 2.38% to 3.72%, dry matter from 12.67% to 21.26%, and carbohydrate content from 88.84% to 92.91%. The ripeness stage of the fruit influences its chemical composition. On a dry basis, unripe plantain peels contain approximately 33–43% dietary fiber, 6–10% protein, 6–12% ash, 2–6% lipids, and 11–39% starch (Agama-Acevedo *et al.,* 2016).

Plantain flour is typically made by peeling mature unripe plantains, slicing the pulp into chips, and drying them under the sun or with mechanical ovens. After achieving a safe moisture content (around 13%), the chips are milled into flour. This flour can be reconstituted in boiling water to form a gelatinized paste—commonly known as *amala ogede* in Yoruba, *Ebue* in Ogoni, and *foufou* in Cameroon—and is consumed with various soups and sauces. It is also used to prepare local dishes like *akara* and *Ukpo Ogede*. Due to its health benefits and extended shelf life, unripe plantain flour is increasingly in demand.

An estimated 70 million people in West and Central Africa obtain over 25% of their dietary carbohydrate intake from plantains (Olumba, 2014). Unripe plantain flour is a key ingredient in traditional dishes, including *akara*, *ukpo ogede*, baked goods, and soups. It is also commonly reconstituted in boiling water to make *amala*, a smooth paste consumed with soups (Onuoha *et al.,* 2014). Traditionally, *amala* is made from blanched or dried yam, cassava, sweet potato, or unripe plantain flour by stirring into boiling water. It is typically wrapped in low-density polyethylene or polypropylene sheets and stored in food flasks for up to 48 hours (Fetuga *et al.,* 2014). In Southwestern Nigeria, some prefer wrapping it in local leaves like *Ewe Eran* (*Thaumatococcus daniellii*) or *Ewe Gbodogi* (*Megaphrynium macrostachyum*) to preserve aroma and texture (Akinfenwa, 2018; Awoyale *et al.,* 2020). Owing to its low glycemic index, unripe plantain flour-based *amala* is gaining popularity, particularly among diabetic individuals.

Nigeria remains one of Africa's top producers and consumers of plantains, ranking among the world's top 20 plantain-producing countries (FAO, 2006). In recent years, it has contributed substantially to the income of rural households. Unlike other starchy staples whose demand decreases with rising income, the demand for plantain continues to rise (Akinyemi *et al.,* 2010). Studies have indicated that unripe plantain peels contain higher levels of fat, ash, crude fiber, and carbohydrates than ripe peels. Over 60 varieties of plantain have been identified, classified into Giant French, Medium or Small French, and Dwarf French types. The International Institute of Tropical Agriculture (IITA) has developed pest-resistant, high-yielding cultivars with improved postharvest qualities (Idumah *et al.,* 2016) (Figure 1).

In contrast, the bean pod (*Brachystegia eurycoma*), a leguminous plant of the Fabaceae family, is native to tropical Africa and commonly found along riverbanks and swamps in Western and Eastern Nigeria (Okwu and Okoro, 2006). It is widely used as a food crop and culinary additive, especially as a thickening and flavoring agent in traditional soups. It is known by various local names including *okung* (Efik), *eku* (Esan), *achi* (Igbo), *ekalado* or *eku* (Yoruba), *okweri* (Edo), and *akpakpa* or *taura* (Hausa) (Figure 2).

The gum exudate of *B. eurycoma* has been traditionally used for wound healing (Adikwu and Enebeke, 2017), and it is believed to help retain body heat, thus aiding in

Figure 2. Seeds of bean pod (*Brachystegia eurycoma)* **Source:** Ikegwu *et al.,* 2010.

temperature regulation (Onimawo and Egbekun, 1998). In Cameroon, its gastrointestinal benefits have been reported (Uzomah and Ahiligwo, 1999). The seeds are said to soften bulky stools and have been associated with reduced risk of colon and rectal cancers (Ndukwu, 2009).

The seed flour is rich in carbohydrates and dietary fiber and is widely used in Southeastern Nigeria as a flavoring and thickening agent (Okoli *et al.,* 2015; Uhuegbu *et al.,* 2009, 2010). In traditional medicine, it is used to regulate temperature, improve digestion, and support gastrointestinal health (Ndukwu, 2009). Phytochemical analyses have revealed the presence of bioactive compounds such as flavonoids, phenolics, alkaloids, saponins, and tannins. Additionally, it is a good source of macronutrients including proteins, lipids, and minerals (Okwu and Okoro, 2006).

Various parts of the plant have demonstrated pharmacological effects, including analgesic, anti-inflammatory, antimicrobial, wound healing, antioxidant, anticancer, antidiabetic, and hepatoprotective properties. These functional attributes highlight the potential of *B. eurycoma* as a valuable nutritional supplement.

Therefore, this study seeks to evaluate the nutritional composition and pasting properties of unripe *Musa paradisiaca* flour supplemented with *Brachystegia eurycoma* seed flour. The aim is to explore the functional food potential of this composite blend and its application in improving the nutritional profile and shelf life of traditional flours.

MATERIALS AND METHODS

Collection of samples

Bunches of unripe plantain were bought at a local market in Malete, Kwara State, Nigeria, while bean pod seed sample was bought at a local market in Ilorin, Kwara State, Nigeria.

Chemicals and reagents

Ethanol, iodine solution, sulphuric acid, phenol solution, acetic acid (57.75 ml, glacial acetic acid in 1000 ml), NAOH 1N (40 g in 1000 ml), distilled water and perchloric acid were obtained from the Department Laboratory, Malete, Kwara State, Nigeria and the reagents were of analytical grade.

Preparation of sample composite

Unripe plantains were cut from the branch, rinsed and peeled, the pulp was cut into uniform slices approximately 2–3 cm thick and air dried for a week while the bean pod were rinsed and left to dry for the same period. The air-dried plantains and bean pod were ground into flour using a standard laboratory blender, after which, they were packed in an airtight plastic container and stored at room temperature for further analysis.

Subsequently, percentage by mass of both the unripe plantain and bean pods were weighed out using a standard laboratory analytical balance as follows: Five blends were formulated: 100% URPF, 100% BPF, and three composites—URPF:BPF (96:4, 92:8, and 88:12). Each blend was mixed using a standard laboratory blender and stored in airtight containers at room temperature until analysis

PROXIMATE ANALYSIS DETERMINATION

Determination of moisture content

The moisture content of the samples was determined using AOAC (2005) method by weighing 5 g of each sample into already-weighed, clean drying cans. The cans with the samples were then placed in an oven (Fisher Scientific Co. USA; model 655F) maintained at 105°C for 16-18 h. Thereafter, the drying cans with contents were transferred into a desiccator to cool, and the final weight was taken. The moisture content was then calculated.

Determination of ash content

Ash content of the samples was determined according to AOAC (2005) method. Briefly, 2 g of the sample was weighed into already dried and weighed crucible. The crucible containing the sample was then transferred into the muffle furnace (Fisher Scientific Co. USA, model m186A), maintained at 600°C to incinerate the sample for 6 h until there were no black specks. The crucibles were transferred into a desiccator to cool, after which the final weight was taken and the ash content was calculated.

Determination of protein content

Protein content of the samples was determined using micro-Kjeldahl method (Foss Analytical, 2003). A portion of 0.20 – 0.25 g of the sample was weighed into the digestion tube, to which 4 mL each of concentrated H_2SO_4 and H_2O_2; and one tablet of Kjeldahl catalyst were added. The sample was digested on the digestion block at 420°C for 1 h.

Thereafter, the NH_3 in the digestate was distilled into a boric acid receiver solution (1% boric acid containing bromocresol green/methyl red indicator), in the presence of a strong alkali (40% NaOH); and titrated against 0.1 M HCl using automated Kjeldahl analyzer (Kjeltec 2300). Then the % nitrogen (N) obtained from the titration was converted to % protein by multiplying by 6.25.

Determination of fat content

Fat content of the samples was determined according to AOAC (2005) method. A portion of 3 g of the sample was weighed into dried thimble and plugged with cotton wool. The thimble was then inserted

Table 1. Nutritional proximate composition of the samples.

Sample	Protein	Ash	Carbohydrate	Moisture	Fat	Food Energy
100% URPF	10.19±0.08[a]	2.53±0.49[a]	78.59±0.47[d]	7.77±0.11[a]	0.93±0.04[c]	363.42±2.51[e]
100% BPF	10.09±0.05[a]	3.24±0.13[a]	77.89±0.56[d]	5.50±0.18[a]	3.30±0.21[a]	381.58±0.26[e]
96% URPF:4% BPF	9.91±0.04[b]	2.54±0.21[a]	78.29±0.40[d]	7.58±0.13[a]	1.68±0.27[b]	367.90±1.05[e]
92% URPF:8% BPF	9.91±0.04[b]	2.49±0.01[a]	78.49±0.21[d]	7.37±0.19[b]	1.75±0.04[b]	369.35±0.60[e]
88% URPF:12% BPF	9.91±0.04[b]	2.44±0.10[a]	78.69±0.21[d]	7.15±0.17[a]	1.83±0.21[b]	370.81±0.45[e]

Data represent the mean ± standard deviation of duplicate readings; values with the same lower case superscript letter along the same column are not significantly different (p<0.05). **URPF**- Unripe plantain flour; **BPF**-Bean flour.

Table 2. Pasting properties of unripe plantain and bean pod composite flour samples.

Sample	Peak 1 Viscosity (RVU)	Trough 1 Viscosity (RVU)	Breakdown Viscosity (RVU)	Final Viscosity (RVU)	Setback Viscosity (RVU)	Peak Time (Min.)	Pasting Temp. (°C)
100% URPF	193.25	159.17	34.08	243.83	84.67	5.60	83.25
100% BPF	1023.50	878.92	144.58	1064.08	185.17	7.00	84.10
96% URPF; 4% BPF	118.98	112.98	6.00	191.00	78.02	5.71	85.01
92% URPF; 8% BPF	188.38	184.06	4.33	352.00	167.94	6.35	84.37
88% URPF; 12% BPF	257.78	255.14	2.67	513.00	257.86	6.99	83.73

Data represent the mean ± SD (standard deviation). One-way analysis of variance was used to test for significant group differences. **URPF**- Unripe plantain flour. **BPF** - Bean pod flour.

into extraction unit (Soxtec HT unit). Then, 50 mL of hexane was dispensed into a dried and pre-weighed extraction cup, and loaded in the extraction unit. The sample was extracted for 15 min in boiling mode, and for 30-45 min in rinsing mode, after which, the hexane was evaporated. The cup containing the fat was removed and oven-dried at 100°C for 30 min. Then, the cup was cooled in a desiccator, and the final weight was measured. The percentage (%) fat content was subsequently calculated.

Determination of carbohydrate content

The total carbohydrate content of the samples was determined by difference, by subtracting the sum of percentage of moisture, ash, protein and fat contents from 100.

Statistical Analysis

Data was expressed as mean ± SD (standard deviation) of duplicate readings. One-way analysis of variance was used to test for significant group differences.

RESULTS AND DISCUSSION

The results presented in Table 1 (proximate composition) show that there were no significant differences (p>0.05) among all flour samples in terms of their protein, ash, and carbohydrate content. Moisture content was highest in the 100% unripe plantain flour (URPF) sample at 7.77 ± 0.11%, which falls within the range of 6.50 ± 0.24% to 10.0 ± 0.00% as previously reported by Adenugwa *et al.* (2017). Conversely, the lowest moisture content was observed in the 100% bean pod flour (BPF) sample, recorded at 5.50 ± 0.18%. The composite blends—88% URPF:12% BPF, 92% URPF:8% BPF, and 96% URPF:4% BPF—showed slight variations in moisture content, with values of 7.15 ± 0.17%, 7.37 ± 0.19%, and 7.58 ± 0.13%, respectively.

According to Ashworth and Draper (1992), products with moisture content greater than 12% are more susceptible to microbial spoilage and typically have shorter shelf lives. Therefore, the relatively low moisture content of all the flour blends in this study suggests enhanced shelf stability and reduced risk of microbial contamination. In terms of energy content, 100% BPF recorded the highest value at 381.58 ± 0.26 kcal, while the 100% URPF sample had the lowest at 363.42 ± 2.51 kcal. The composite samples (96:4, 92:8, and 88:12 URPF:BPF) had intermediate energy values that did not differ significantly (p>0.05).

As shown in Table 2 (pasting properties), the 100% BPF sample exhibited the highest values across all pasting parameters, except for setback viscosity and pasting temperature. The highest setback viscosity (257.86 RVU) was observed in the 88% URPF:12% BPF blend, while the highest pasting temperature (85.0°C) was recorded in the 96% URPF: 4% BPF blend. A general trend of increasing final viscosity and decreasing breakdown viscosity was observed with higher BPF substitution as reported by Adenugwa *et al.* (2017).

An increase in setback viscosity typically indicates a higher tendency for retrogradation during cooling. However, depending on product type, this can also enhance gel strength and shelf stability during cooling and consequently, lower staling tendencies in products made from the flour blends. The enhanced pasting properties of the 100% BPF sample align with findings by Irondi *et al.* (2021) and may justify its suitability in diverse food applications. The 96% URPF: 4% BPF blend had the lowest peak and trough viscosities, while the 92% URPF:8% BPF and 88% URPF:12% BPF blends exhibited significant variation in pasting characteristics. These properties suggest that BPF inclusion may be beneficial in formulations requiring improved gel strength and energy density, such as weaning foods or bakery products.

Safety and Sensory Considerations

While *Brachystegia eurycoma* flour (BPF) has shown promising functional and nutritional properties such as improved setback viscosity and energy content; its safety profile and sensory characteristics are also critical for its potential adoption in food formulations.

Safety Considerations

The use of BPF in traditional soups and folk medicine across various Nigerian communities suggests a long history of safe consumption. However, like many legume-based ingredients, BPF may contain antinutritional factors such as tannins, saponins, oxalates, and phytates, which can interfere with nutrient bioavailability if not properly processed. Cheng and Langrish (2025); Ayalew *et al.* (2024) and Ejidike *et al.* (2024) have reported that appropriate drying, roasting, or boiling significantly reduces these compounds, making the flour safe for consumption. The composite flour in this study underwent air drying and heat-based analysis, both of which are known to minimize antinutritional elements. Nevertheless, further toxicological assessments and clinical evaluations would be beneficial to fully validate its safety for large-scale consumption, especially in vulnerable populations like infants and the elderly.

Sensory Implications

Brachystegia eurycoma is widely used as a thickener in traditional soups due to its gel-forming ability and mild flavor, making it generally acceptable in native dishes. However, its distinctive taste, color, and aroma could affect consumer acceptance when used in unconventional products such as baked goods or porridges. Irondi *et al.* (2021) reported that up to 10% incorporation of BPF in gluten-free bread formulations maintained acceptable sensory qualities. In this study, increasing BPF levels resulted in pasting and compositional changes that may influence mouthfeel, texture and color. Thus, sensory evaluation trials should be conducted in further studies to determine optimal substitution levels that balance functionality with consumer preference.

Conclusion

The results of this study indicate that the supplementation of unripe plantain flour with *Brachystegia eurycoma* flour can effectively enhance its nutritional profile and functional properties without compromising its stability. Although no significant differences were observed in protein, ash, and carbohydrate content across the blends, the incorporation of bean pod flour notably reduced moisture content, potentially extending shelf life. The composite flours exhibited improved energy values and setback viscosities, with the highest setback recorded in the 88% URPF:12% BPF sample, indicating better stability and reduced staling tendency. Additionally, the pasting temperature of the 96% URPF:4% BPF blend was highest, suggesting suitability for thermal processing. Overall, the study demonstrates that bean pod flour can be a valuable supplement in the formulation of functional flours, suitable for use in the preparation of diverse food products including therapeutic diets and complementary infant foods.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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