

Nutritional Composition, Browning Index, Color Dynamics, And Cooking Quality Of Noodles From Wheat-Unripe Plantain Flour Blends.

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Abstract

Aim: Noodle production in sub-Saharan Africa is determined by the ultra-refined and imported wheat flour. This significantly contributes to foreign exchange expenditure and dietary imbalance.

Study Design: This study evaluated the nutritional composition, mineral and vitamin profiles and cooking quality of noodles formulated from composite blends of wheat and unripe plantain (*Musa paradisiaca* L.). The ratios used were 80:20 (A), 60:40 (B), and 70:30 (C) against a 100% wheat flour control.

Methodology: Proximate, mineral and vitamin analyses were conducted using AOAC methods, while cooking yield and cooking loss were determined gravimetrically.

Results: The results showed that plantain addition significantly ($p < 0.05$) increased crude fiber (up to 7.44 g/100g), protein (up to 13.95 g/100g), ash (up to 3.34 g/100g) and all the analyzed minerals and B-vitamins relative to the control. Moisture and carbohydrate were the highest in the control (7.89 g/100g and 79.55 g/100g, respectively). Cooking yield was highest in the control (285.55%), while cooking loss was lowest (3.63%). This indicated slight quality trade-offs at higher substitution levels. The 60:40 blend demonstrated the most favorable overall nutritional profile.

Conclusion: Findings suggest that unripe plantain flour is a viable, nutritionally superior partial substitute for wheat in noodles production. This is important for food security and metabolic disease management and agro-industrial value chain development in Nigeria.

Keywords: Functional noodles; Unripe plantain; Wheat flour blend; Proximate composition; Minerals; B-vitamins; Nigeria.

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I. Introduction

Noodles are one of the globally important staples due to their convenience, palatability, affordability, and diverse cultural adaptability. The annual global production of noodles is estimated at 100 billion servings (Hou, 2010). In Nigeria alone, noodles have achieved remarkable market penetration, especially among urban populations, school-aged children and low-income households (Ejigui et al., 2005). Noodles are traditionally produced from wheat, which gives them the gluten-endowed structural integrity. Nigeria spends an estimated 2.7 billion USD on wheat imports, which exerts a sustained pressure on foreign exchange reserves and food price stability (FAO, 2022). Beyond the economic dimension, refined wheat-based noodles are characteristically poor in dietary fiber, micronutrients, especially B-vitamins, and slowly digestible carbohydrates (Aniemena et al., 2024). Dietary limitations have been blamed as the major causes of diet-related non-communicable diseases (NCDs). NCDs, including type 2 diabetes, obesity, and cardiovascular diseases, account for about 29% of mortality cases in Nigeria (WHO, 2023; Nwagbo et al., 2025). Various flour enrichment programs are used to augment these losses in refined wheat flour. However, nutrient-dense, locally available food materials can provide a cheaper, more nutritious alternative to nutrient-enriched, imported wheat flours. There is, therefore increased local drive to utilize locally available, nutrient-dense crops as supplements or replacements to wheat flour in food systems.

Unripe plantain (*Musa paradisiaca*) is a widely available crop indigenous to the tropics. Unripe plantain flour presents a nutritionally compelling and agronomically strategic alternative for partial wheat replacement in

composite flour application. It is cultivated in over 30 states in Nigeria, with an annual production exceeding 2.7 million tonnes (FAOSTAT, 2022). It is rich in complex carbohydrates, resistant starch (30-40 g/100g), bioactive phenolic compounds, dietary fiber, and essential micronutrients, including B-vitamins and provitamin A carotenoids. The flour of unripe plantain is exceptionally rich in potassium, magnesium, and iron (Agama-Acevedo et al., 2016; Ovando-Martinez et al., 2009). Additionally, unripe plantain flour can improve glycaemic response, gut health, and satiety of cereal-based food products (Aparicio-Saguilan et al., 2007).

These nutrients are crucial for metabolic and physiological functions. Wheat flour replacement using unripe plantain could therefore improve nutrient density and create diversified food products with enhanced functional health-promoting benefits (Okpalanma et al., 2024).

Previous research studies on wheat-plantain composite noodles were focused on proximate composition, functional properties, and sensory evaluation. The studies reported increased fiber and ash content and a corresponding reduced protein content with increased unripe plantain substitution. Such findings provide useful baseline information, but are limited in micronutrient profiling, especially on B-vitamins and carotenoid composition. Dietary B-vitamins and carotenoids are important for immune support, visual health, and the prevention of micronutrient deficiencies, especially in regions where hidden hunger remains a major public health challenge (Okpalanma et al., 2025).

Unripe plantain is recognized as a good source of essential minerals. However, there is limited data on the mineral composition of wheat-unripe plantain noodles and their bioavailability and retention levels affected by processing. This limits the ability to position wheat-plantain noodles as nutritionally functional products.

From a quality standpoint, color and browning effects are critical in wheat-plantain noodles. Plantain flour introduces pigments and browning substrates that can significantly affect the sensory acceptability and marketability of the product. However, these, especially the browning index, color change dynamics, and instrumental color parameters, have not been explored in previous studies. These are needed for product appearance optimization. Similarly, the cooking quality of wheat-unripe plantain noodles as affected by varying levels of plantain flour supplementation is underreported in previous studies. Cooking quality, such as cooking yield and cooking loss, is usually negatively affected by gluten dilution in composite noodles. Cooking yield reflects the water absorption and swelling capacity of noodles, while cooking loss shows the extent of solid leaching into cooking water. These are linked to the structural integrity, consumer perception, and acceptability of noodle products.

This study synergistically integrated the nutrient composition and quality studies of wheat-plantain noodles at varying plantain flour levels, against a 100% wheat flour control, to establish a standardized formulation and processing conditions. Therefore, this study aimed to (i) assess the proximate (moisture, ash, crude fiber, fat, protein and carbohydrate); (ii) evaluate the mineral composition (calcium, potassium, iron, magnesium, selenium and sodium); (iii) Assess the vitamin content (B-vitamins: B2, B3, B6 and B9 and vitamin A); (iv) determine the cooking loss and cooking yield and (v) determine the color changes and browning index of noodles produced from various wheat and unripe plantain flour blends in comparison to wheat flour control. The findings are expected to fill critical knowledge gaps, support the utilization of indigenous crops, and contribute to the advancement of composite flour technology for sustainable and functional food development. This knowledge is especially important to food product developers, NAFDAC regulatory policy, agro-industrial value chain actors, and public health nutritionists in Nigeria and sub-Saharan Africa.

II. Materials And Methods

Raw Material Procurement and Preparation

Mature, but physiologically unripe plantain fingers (*Musa paradisiaca* L., Agbagba variety) at stage 1-2 of the Gross Michelle colour chart were obtained from Eke-Awka, Anambra State, Nigeria. A 100 % wheat semolina flour was sourced from a certified dealer. Unripe plantain flour was peeled, sliced at 3 mm thickness, oven-dried at 60 °C for 18 hours, milled using a hammer mill, and sieved through a 250 µm mesh sieve.

Composite Flour Formulation and Noodle Production

Wheat flour and unripe plantain flour were blended at ratios of 80:20 (sample A), 60:40 (sample B), and 70:30 (sample C) on a weight-to-weight basis. A 100 % wheat flour formulation was used as the control. Noodles were produced by weighing 200 g of each composite flour blend with 2% salt and sufficient water (approximately 35 mL/100g flour) to form a stiff dough. The dough was sheeted through a manual pasta machine at 2 mm thickness, cut into 15 cm strands and dried in a dehydrator at 50 °C for 6 hours to achieve a moisture content of <13%.

Proximate Composition Analysis

Moisture content, ash, crude fiber, crude fat, and crude protein were determined by the methods of the Association of Official Analytical Chemists (AOAC, 2019). Moisture was measured by hot air oven drying to

constant weight at 105 °C. Ash content was measured by incineration at 550 °C in a muffle furnace. Crude fat was measured by Soxhlet extraction with petroleum ether. Crude fiber was measured by sequential acid-alkali digestion, while crude protein was measured by the Kjeldahl method (N× 6.25). Total carbohydrate was calculated by difference.

Mineral and Vitamin Analysis

Mineral content (calcium, potassium, iron, magnesium, selenium, and sodium) was determined by the wet acid digestion method. This was followed by atomic absorption spectrophotometry (AAS) using a Perkin-Elmer (AOAC, 2019). Sodium and potassium were determined by flame photometry. Vitamin B2 (riboflavin), B3 (niacin), B6 (Pyridoxine), B9 (folate) and vitamin A (as retinol equivalent) were quantified by high-performance liquid chromatography (HPLC) with UV detection following aqueous acid extraction and enzyme hydrolysis procedures as described by the AOAC method 970.65 and subsequent modifications.

Cooking Quality Determination

Cooking yield and cooking loss were determined gravimetrically according to the method of AACCI International (2010). Noodle strands (10 g) were cooked in 250 mL distilled water at 100 °C for the optimum cooking time (time to disappearance of white core), drained, blotted, and weighed. Cooking yield was expressed as the percentage weight gain of cooked noodles relative to uncooked weight. Cooking loss was determined by evaporating the cooking water to dryness and expressing the residual as a percentage of the original sample weight.

Statistical Analysis

All analyses were conducted in triplicate. Data are expressed as means ± standard deviation (SD). One-way analysis of variance (ANOVA) was performed, and means were separated by Duncan’s Multiple Range Test (DMRT) at a significance level of p<0.05, using SPSS version 26.0 (IBM Corp., Armonk, NY, USA).

III. Results

Proximate Composition

Table 1 presents the proximate composition of noodles produced from wheat-unripe plantain composite flour. Moisture content ranged from 5.16-7.89 g/100g from sample A having 30% plantain flour to the control. All the composite samples had significantly (p<0.05) lower moisture content than the 100 % wheat flour control. Ash content was significantly highest in sample A (3.34 g/100g) and lowest in the control (1.07 g/100g). This reflects the contribution of the unripe plantain’s mineral-bearing fraction. Crude fat was highest in sample A (5.59 g/100g) and decreased progressively with increasing plantain flour addition. The control sample had the lowest value of crude fiber (1.90/100g). Crude fiber was significantly higher in all composite samples (5.79-7.44 g/100g with sample C and A having the lowest and highest values, respectively) compared to the control (2.82 g/100g). Protein content was significantly superior in sample A (13.95 g/100g) and significantly lower in the control (7.77 g/100g). Total carbohydrate was highest in the control (78.55 g/100g) and lowest in sample A (65.77 g/100g)

Table 1: Proximate Composition of Wheat-Unripe Plantain Flour Noodles

Proximate Composition (mg/100g)	A	B	C	Control
Moisture	5.16 ^d ±0.06	6.04 ^c ±0.01	6.85 ^b ±0.12	7.89 ^a ±0.03
Ash	3.34 ^a ±0.32	2.28 ^b ±0.24	1.86 ^c ±0.02	1.07 ^d ±0.01
Crude fat	5.59 ^a ±0.04	4.36 ^b ±0.03	3.64 ^c ±0.05	1.90 ^d ±0.07
Crude fiber	7.44 ^a ±0.13	7.34 ^a ±0.16	5.79 ^b ±0.23	2.82 ^c ±0.06
Protein	13.95 ^a ±0.05	12.45 ^b ±0.47	10.53 ^c ±0.04	7.77 ^d ±0.03
Carbohydrate	64.52 ^d ±0.43	67.53 ^c ±0.30	71.33 ^b ±0.91	78.55 ^a ±0.01

Mean±SD across the same row having the same superscript are not significantly different.
 A = wheat:plantain flour (70:30%); B =wheat:plantain flour (80:20%) and C=wheat:plantain flour (90:10%)
 and Control=100% wheat flour

Mineral Composition

Significant differences (p<0.05) were observed in the mineral composition across all formulations, with sample A (70:30 wheat:plantain) having the values for all mineral parameters assessed. (Table 2). Calcium was highest in sample A (12.85 mg/100g) and declined with increasing plantain substitution. All composite samples significantly exceeded the control (7.40 mg/100g). Potassium was also highest in sample A (11.52 mg/100g), while the control had the lowest score (5.48 mg/100g). Iron and magnesium were significantly enriched in composite samples relative to the control, with sample A having the highest value (14.53 mg/100g and 15.33 mg/100g, respectively). Iron was also highest in sample A (12.48 mg/100g). Selenium was markedly elevated in

sample A (14.53 mg/100g) compared to the control (8.33 mg/100g). Sodium was highest in sample A (23.14 mg/100g) and lowest in the control (8.34 mg/100g).

Table 2: Mineral Composition of Wheat-Unripe Plantain flour noodles

Mineral Composition (mg/100g)	A	B	C	Control
Calcium	12.85 ^a ±0.07	11.92 ^b ±0.09	10.60 ^c ±0.10	7.40 ^d ±0.08
Potassium	11.52 ^a ±0.01	10.51 ^b ±0.07	9.38 ^c ±0.06	5.48 ^d ±0.01
Iron	12.48 ^a ±0.11	11.39 ^b ±0.06	9.54 ^c ±0.04	9.43 ^c ±0.04
Magnesium	15.33 ^a ±0.24	14.43 ^b ±0.03	12.28 ^c ±0.24	9.32 ^d ±0.03
Selenium	14.53 ^a ±0.04	10.55 ^b ±0.02	9.21 ^c ±0.01	8.33 ^d ±0.02
Sodium	23.14 ^a ±0.03	20.18 ^b ±0.08	13.96 ^c ±0.02	8.43 ^d ±0.04

Mean±SD across the same row having the same superscript are not significantly different.
A= wheat:plantain flour (70:30%); B =wheat:plantain flour (80:20%) and C=wheat:plantain flour (90:10%) and Control=100% wheat flour

Vitamin Composition

Table 3 shows the vitamin composition of all the noodle formulations. All composite samples contained significantly higher concentrations of B-vitamins with sample A (70:30) having the highest values. Vitamin B2 (riboflavin) was highest in sample A (3.85 mg/100g) and lowest in the control (0.95 mg/100g). Vitamin B3 (niacin) also recorded the highest value in (5.85 mg/100g) in sample A against the control. Vitamin B6 also decreased with plantain flour substitution, with sample A and the control having the highest and lowest values (3.97 and mg/100g), respectively. Vitamin B9 (folate) increased with plantain substitution, with sample A having the highest value (2.47), and the control (100% wheat recorded the least value. The range of vitamin A in the samples was 1.06-1.97 mg/100g, with the control having the least and sample A having the highest value.

Table 3: Vitamin Composition of Wheat-Unripe Plantain flour Noodles

Vitamin Composition (mg/100g)	A	B	C	Control
Vitamin B2	3.85 ^a ±0.21	3.65 ^a ±0.15	2.52 ^b ±0.06	0.95 ^c ±0.01
Vitamin B3	5.85 ^a ±0.01	5.75 ^a ±0.01	4.18 ^b ±0.08	1.77 ^c ±0.01
Vitamin B6	3.97 ^a ±0.21	3.73 ^b ±0.21	3.43 ^c ±0.03	1.29 ^d ±0.08
Vitamin B9	2.47 ^a ±0.02	2.25 ^b ±0.03	2.14 ^c ±0.03	1.98 ^d ±0.01
Vitamin A	1.97 ^a ±0.71	1.40 ^b ±0.01	1.35 ^b ±0.04	1.06 ^c ±0.01

Mean±SD across the same row having the same superscript are not significantly different.
A= wheat:plantain flour (70:30%); B =wheat:plantain flour (80:20%) and C=wheat:plantain flour (90:10%) and Control=100% wheat flour

Cooking Yield and Cooking Loss

Table 4 shows the cooking yield and cooking loss values. Cooking yield was significantly highest in the control (285.55%) and lowest in sample A (267.13%). Samples B and C had intermediate values. Cooking loss showed the reverse pattern. The lowest value (3.63%) was recorded in the control, while the highest value (6.13%) was seen in sample A. A higher cooking loss value indicated that higher plantain flour substitution led to increased starch leaching into the cooking water.

Table 4: Cooking Yield and Cooking Loss of Wheat-Unripe Plantain flour noodles

	A	B	C	Control
Cooking Yield	279.54 ^b ±0.04	267.13 ^d ±0.02	275.03 ^c ±0.66	285.55 ^a ±0.02
Cooking Loss	4.63 ^c ±0.10	6.13 ^a ±0.03	5.19 ^b ±0.01	3.63 ^d ±0.31

Mean±SD across the same row having the same superscript are not significantly different.
A= wheat:plantain flour (70:30%); B =wheat:plantain flour (80:20%) and C=wheat:plantain flour (90:10%) and Control=100% wheat flour

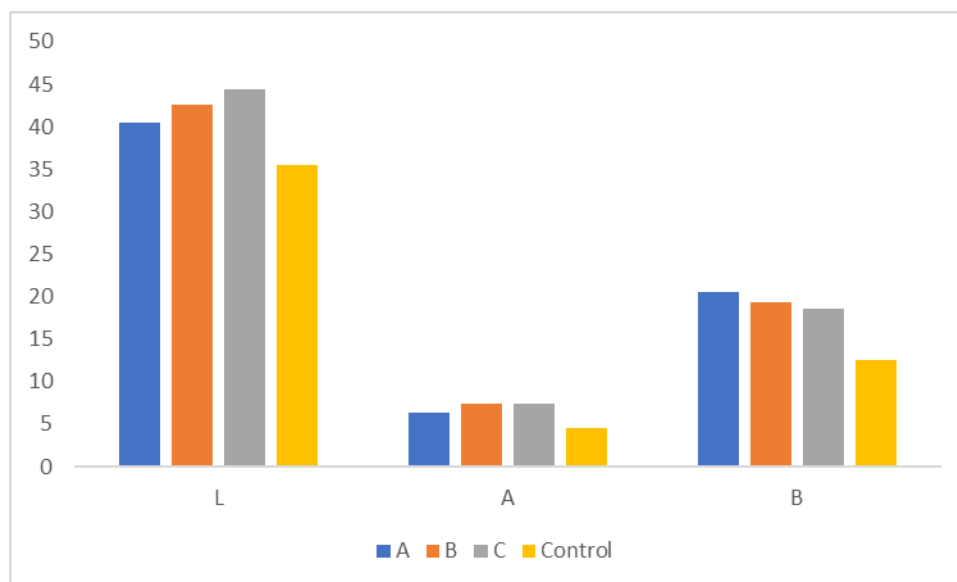


Fig 1: Color Analysis of Wheat-Unripe Plantain flour noodles.

A= wheat:plantain flour (70:30%); B =wheat:plantain flour (80:20%) and C=wheat:plantain flour (90:10%) and Control=100% wheat flour

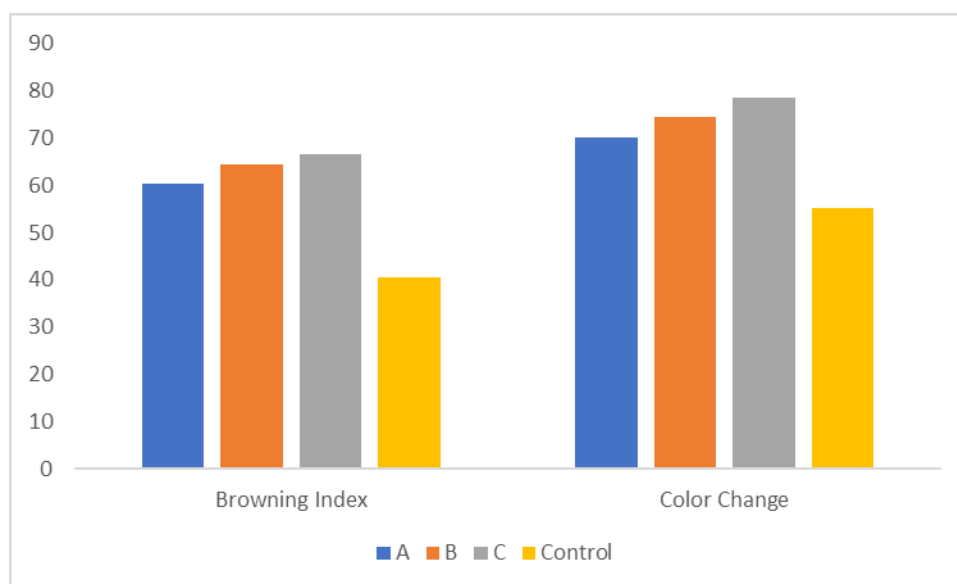


Fig 2: Browning Index and Color Change of Wheat-Unripe Plantain flour noodles

A= wheat:plantain flour (70:30%); B =wheat:plantain flour (80:20%) and C=wheat:plantain flour (90:10%) and Control=100% wheat flour

IV. Discussion

The progressive decline in moisture content with increasing plantain flour substitution is consistent with the lower equilibrium moisture content of plantain flour relative to refined wheat flour. This could be attributed to the higher resistant starch content of plantain flour and its associated reduced hygroscopicity (Ovando-Martinez et al., 2009). Lower moisture content in composite noodles is advantageous for a lower water activity and longer shelf stability (Fabian and Ju, 2011). The significant enrichment of crude fiber in plantain-enriched samples is of particular public health importance. The WHO recommends a daily dietary fiber intake of 25 g for adults (WHO, 2023). A fiber-deficient diet is associated with higher risks of colorectal cancer, dyslipidaemia and type 2 diabetes. Unripe plantain is rich in non-starch polysaccharides and resistant starch type 2, which confer prebiotic properties (Faisant et al., 1995). The high fiber level of sample A, particularly positions the noodle product as functional, which could be useful in the management of type 2 diabetes and other metabolic diseases (IDF, 2021). The marked improvement in crude protein from 7.77 g/100g to 13.95 g/100g in sample A is noteworthy with respect to the burden of protein-energy malnutrition in Nigeria (NBS, 2022). Plantain flour, though not a primary protein

source contains a moderate concentration of essential amino acids when blended with wheat's gluten proteins, may produce a complementary amino acid profile (Akubor and Ukwuru, 2003). Importantly, the protein levels in sample A approach the FAO/WHO-recommended protein levels for cereal-based complementary foods (>15 g/100g DW). This suggests protein utility in formulations that target children aged 6-36 months.

The mineral data suggest that plantain flour substantially elevated the micro- and macro-mineral density of the composite noodles. The elevated potassium levels (up to 11.52 mg/100g). Sample A is consistent with the known potassium richness of plantain and carries clinical relevance. Dietary potassium is inversely associated with hypertension risk, and the WHO recommends a daily potassium intake of 3,510 mg for adults (WHO, 2023). The enhanced iron and magnesium contents across composite samples are similarly important, given the high prevalence of iron-deficiency anemia (25.3% in women of reproductive age) and widespread magnesium insufficiency in the Nigerian population (NDHS, 2021). The elevated selenium in sample A is notable, as selenium functions as a cofactor for glutathione peroxidase and thioredoxin reductase. These enzymes are critical to antioxidant defense and thyroid metabolism (Rayman, 2012).

The substantially higher B-vitamin concentrations in all composite samples relative to the control corroborate the established vitamin profile of unripe plantain. Riboflavin (B2) and niacin (B3) play central roles in mitochondrial energy metabolism. The elevation of these vitamins in plantain composite noodles is consistent with the findings of Agama-Acevedo et al. (2016) for plantain-based products. The higher folate (B9) in sample C is relevant to maternal health, as adequate periconceptional folate intake is a key preventive factor for neural tube defects (Bailey et al., 2015). The generally higher vitamin A in composite samples over the control may reflect the carotenoid precursors present in plantain's non-starch fraction.

The decline in cooking yield and increase in cooking loss with higher plantain flour substitution shows the structural consequences of gluten network dilution. Gluten proteins from the viscoelastic network that entraps gelatinized starch and water during cooking. Their proportional reduction with each increment of plantain flour weakens the network. This allows greater starch solubilization and leaching during cooking (Hou, 2010). The cooking loss recorded for sample A (6.13 %) remained below the 8% threshold regarded as acceptable for noodles I international trade standards (AACC, 2010). This suggests commercial viability levels up to 40%. These findings align with those of Ayo et al. (2014), who reported acceptable cooking properties in plantain-wheat noodles up to 30% substitution and extend the viable range to 40% when nutritional objectives are prioritized.

V. Conclusion

This study demonstrates that the 40% partial substitution of wheat flour with unripe plantain flour significantly improves the proximate, mineral and vitamin contents of noodles with acceptable cooking quality. The 60:40 wheat plantain formulation (sample A) emerges as the best formulation with the most nutritious advantage. It offers superior protein, fiber, mineral and B-vitamin profiles. While it presents the lowest cooking yield and highest cooking loss among the tested formulations, it was acceptable within commercial standards. This indicates that nutritional enrichment at 40% plantain flour substitution level can be achieved without adverse compromise to cooking quality. These findings position unripe plantain flour as a technically feasible and nutritionally superior wheat supplement for noodle manufacture. The nutritional benefits are also multi-dimensional as it can address a lot of nutrient deficiencies. Besides these benefits, the findings help as a solution to the Nigeria's wheat import dependency and contributes to agricultural value chain development. Future studies should examine the sensory acceptability, glycemic index, shelf-life characteristics and consumer acceptance of these formulations in Nigeria.

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