

Quality evaluation of wheat (*Triticum Aestivum*), unripe plantain (*Musa Paradisiaca*) and fluted pumpkin leaf (*Telfairia Occidentalis*) composite flour

American Journal of Chemistry

Vol. 11, No. 1, 35-49, 2026

e-ISSN:2616-5244



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ABSTRACT

This work evaluated the quality of wheat, unripe plantain, and fluted pumpkin leaf composite flour. Four samples were prepared by blending wheat flour, unripe plantain flour, and fluted pumpkin leaf powder in the ratios 100:0:0, 90:10:0, 85:10:5, and 80:10:10, respectively. The proximate composition, pasting properties, functional properties, antinutrient contents, and colour properties of the samples were determined using standard methods. Moisture, crude protein, crude fat, crude ash, crude fibre, and carbohydrate contents ranged from 5.89-9.22 %, 6.59-10.91 %, 9.40-13.29 %, 2.22-3.54 %, 1.76-3.41 %, and 61.73-68.16 %, respectively. The pasting properties; peak viscosity, trough, breakdown, final viscosity, setback, peak time, and pasting temperature, ranged from 1777.5-2436.5 cP, 933.5-1410.5 cP, 844-1026 cP, 2114.5-2718.5 cP, 1181-1433 cP, 6.00-6.40 minutes, and 71.88-85.20 °C, respectively. Total bulk density ranged from 0.70-0.75 g/ml, water absorption capacity from 0.82-1.02 g/g, and oil absorption capacity from 0.99-1.33 g/g. The antinutrient contents of the samples showed that tannin, phytate, oxalate, and alkaloid contents ranged from 251-268 mg/100g, 184-190 mg/100g, 115-121 mg/100g, and 55.13-57.99 mg/100g, respectively. The results showed that wheat, unripe plantain, and fluted pumpkin leaf powder can be combined to produce an acceptable composite flour improved nutritional quality.

Keywords: Composite flour, Fluted pumpkin leaf, Pasting properties, Unripe plantain, Wheat. Proximate Analyses.

DOI: 10.55284/ajc.v11i1.1998

Citation | Sogunle, K. A., Paul, O. O., & Ramadan, I. A. (2026). Quality evaluation of wheat (*Triticum Aestivum*), unripe plantain (*Musa Paradisiaca*) and fluted pumpkin leaf (*Telfairia Occidentalis*) composite flour. *American Journal of Chemistry*, 11(1), 35-49.

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Funding: This study received no specific financial support.

Institutional Review Board Statement: Not applicable.

Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

Competing Interests: The authors declare that they have no competing interests.

Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

History: Received: 23 August 2026/ Revised: 3 September 2026/ Accepted: 7 October 2026/ Published: 20 October 2026

Publisher: Online Science Publishing

Highlights of this paper

- This study evaluated the nutritional, functional, pasting, anti-nutritional, and colouring properties of composite flours formulated by blending wheat flour with varying proportions of unripe plantain flour and fluted pumpkin leaf powder.
- The inclusion of unripe plantain and fluted pumpkin leaf enhanced the overall nutritional profile.
- Ultimately, the findings demonstrate that these locally available ingredients can effectively supplement wheat flour to produce nutritious, functionally suitable composite flours while helping to reduce reliance on imported wheat.

1. INTRODUCTION

Flour is a fundamental ingredient in the food industry, used primarily in the production of baked goods such as bread, cakes, and pastries. Wheat flour is widely used because of its gluten forming proteins, which are essential for structure and leavening, as well as its nutritional composition, including carbohydrates, protein, dietary fibre, and micronutrients such as iron, zinc, and B vitamins (Iqbal, Shams, & Fatima, 2022). However, in Nigeria and many other developing countries, the high cost and insufficient domestic production of wheat have prompted interest in alternative composite flours to reduce costs and enhance nutritional quality (Abu, 2023). Similar pressures have driven composite flour research elsewhere in Africa: in the Democratic Republic of Congo, partial substitution of wheat with cassava flour fortified with mushroom flour was shown to raise the protein and energy content of bread while easing reliance on imported wheat (Irakiza et al., 2021). Also, blending durum wheat with faba bean flour at levels of up to 40 % has been reported to significantly increase the ash, protein, mineral, and phenolic content of composite bread, underscoring the wider potential of legume and tuber based wheat substitution to address both cost and nutritional deficiencies (Benayad, Taghouti, Benali, Aboussaleh, & Benbrahim, 2021). Composite flours, which are blends of two or more flours, have gained prominence for improving the functional and nutritional properties of food products, including parameters such as water absorption capacity, swelling power, and solubility, which influence product texture, volume, and sensory characteristics (Igwenyi & Ojmelukwe, 2017). Unripe plantain flour is an ideal candidate for composite formulations because of its richness in resistant starch, dietary fibre, vitamins A and C, and minerals such as potassium. These components contribute to digestive health, immune function, and blood pressure regulation (Adeyemi, Longe, & Elemo, 2014). Its resistant starch is particularly noted for fermenting in the colon, which benefits gut microbiota and may reduce the risk of diseases such as type 2 diabetes and colon cancer. Unripe plantain also contains bioactive compounds such as flavonoids, phenolic acids, and tannins with antioxidant and anti inflammatory properties (Onipe & Jideani, 2015). It has been applied in product development, such as bread and noodles, as a functional and gluten free ingredient (Owolabi, Ogunjobi, & Akinpelu, 2015). Fluted pumpkin leaf (*Telfairia occidentalis*), a common West African leafy vegetable, is nutrient dense and contains bioactive phytochemicals with medicinal properties, including anti inflammatory, anticancer, and antidiabetic effects (Nkereuwem, Eseyin, Udobre, & Ebong, 2011). Nutritionally, it enhances the micronutrient profile of composite flours, while functionally it exhibits notable water and oil absorption capacities and emulsifying potential, making it useful in food systems requiring texture stability, such as soups, dressings, and sauces (Lawal, Sanni, Oluwamukomi, Fogliano, & Linnemann, 2021). Despite its extensive use in traditional dishes such as porridges and soups, its inclusion in flour blends remains underexplored. Nigeria's local wheat production is inadequate to sustain demand in the baking and allied industries, so reliance on costly imported wheat continues (Abu, 2023). Moreover, excessive wheat consumption has been linked to health concerns such as intestinal inflammation, immune disorders, and weight gain. By contrast, unripe plantain flour, being high in iron, can help meet the nutritional needs of coeliac and anaemic patients who must avoid gluten and need more iron in their diets (Adeyemi et al., 2014). Although the inclusion of fluted pumpkin leaf may reduce gelation capacity, it enhances

solubility, swelling power, and oil absorption while minimising gruel solid loss and cooking time (Lawal et al., 2021). Therefore, the development of composite flours utilising unripe plantain flour and fluted pumpkin leaf powder presents a promising, sustainable, and nutritionally superior alternative to sole wheat flour. This approach not only improves food product functionality and affordability but also contributes to local agricultural economies and public health. However, while separate studies have reported on wheat composited with unripe plantain flour alone, or with fluted pumpkin leaf alone, no published work appears to have evaluated a ternary blend that combines wheat, unripe plantain flour, and fluted pumpkin leaf powder together, or examined how the two non wheat components interact to influence the proximate composition, pasting behaviour, functional properties, antinutrient content, and colour of the resulting composite flour. This study addresses that gap. The broad objective of this study was to assess the quality of wheat, unripe plantain, and fluted pumpkin leaf composite flour.

2. MATERIALS AND METHODS

2.1. Source of Raw Materials

Unripe plantain and fluted pumpkin leaf used for this study were purchased from Katsina Central Market in Katsina State. The wheat was obtained from Alhaji Bilya Supermarket, Dutsin-Ma, Katsina State, Nigeria. All other equipment was obtained from the Food Science and Technology (FST) Laboratory, Federal University Dutsin-Ma, Katsina State. All chemicals used were of analytical grade.

2.2. Production of Unripe Plantain Flour

The unripe plantain pulp was processed into flour according to the method described by Ojure and Quadri (2012) as shown in Figure 1. The plantain fruits were removed from the bunch, washed with clean water, and blanched at 100 °C for 3 minutes using a water bath to control enzymatic browning. The fruits were immediately cooled and peeled using a sharp knife. The peeled plantains were sliced to an average thickness of 0.5 mm. The sliced plantain was placed on a tray and dried in a cabinet oven at 60 °C for 12 hours. It was milled using a hammer mill (model corona) and sieved through a 500 µm pore size sieve to obtain a fine flour. The flour was packaged in an air tight zip lock bag.

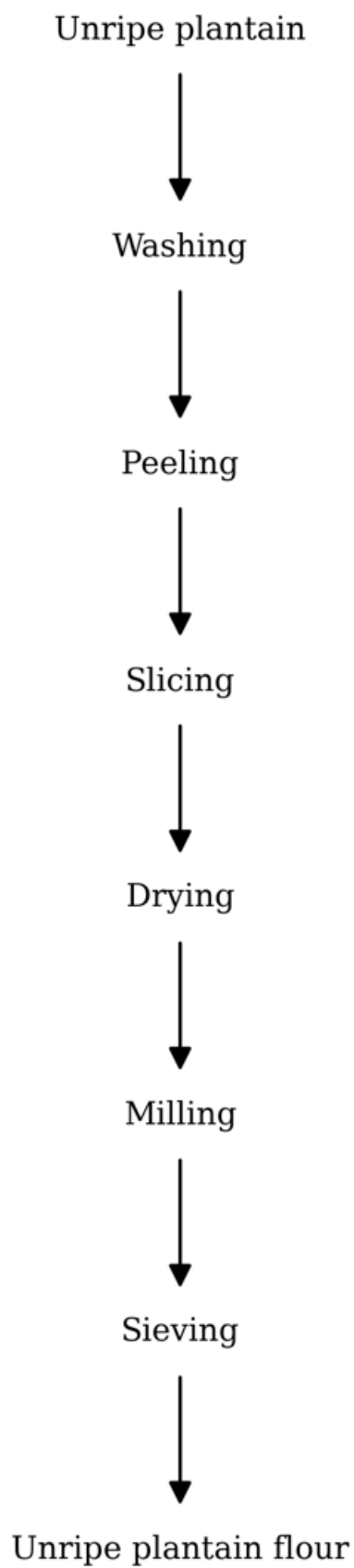


Figure 1. Flow chart for the production of unripe plantain flour.

Source: Ojure and Quadri (2012).

2.3. Production of Fluted Pumpkin Leaf Powder

Fluted pumpkin leaf powder was prepared as shown in Figure 2, using a method modified of Adebowale, Adegoke, Sanni, Adegunwa, and Fetuga (2012). Fresh, matured fluted pumpkin leaves were obtained from the farm. Thereafter, they were sorted, destalked, and rinsed with clean water. The clean leafy vegetable was sliced to size with a clean knife. The sliced vegetable was dried using a hot air cabinet drier at 60 °C for 8 hours. The dried leaves were milled to a fine powder using a Marlex Excella dry mill (Marlex Appliances Pvt., Daman). The blend formulation is presented in Table 1.

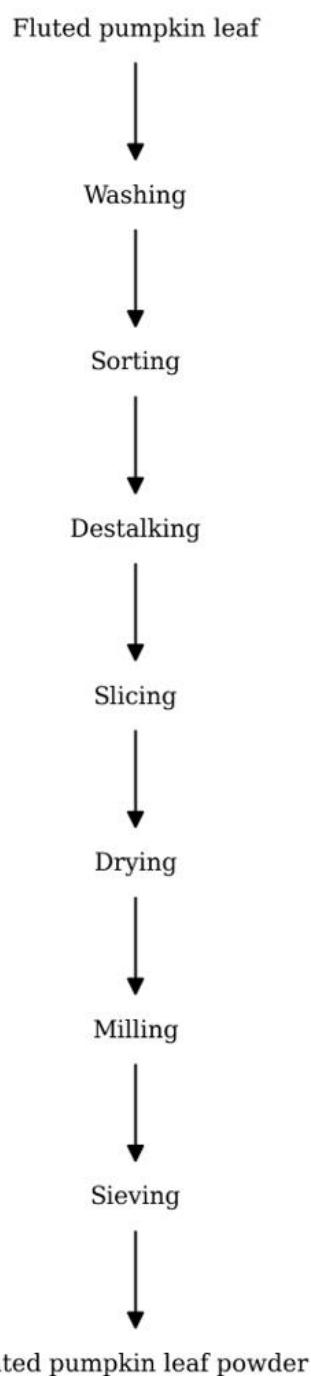


Figure 2. Flow chart for the production of fluted pumpkin leaf powder.

Source: Adebowale et al. (2012) modified.

Table 1. Blend Formulaion.

Sample	Wheat flour (%)	Unripe plantain flour (%)	Fluted pumpkin leaf powder (%)
A	100	0	0
B	90	10	0
C	85	10	5
D	80	10	10

2.4. Proximate Analysis of the Composite Flours

2.4.1. Determination of Moisture Content

Total protein was determined by the Kjeldahl method, as described by [AOAC International \(2023\)](#). Five grams (5 g) of each sample was weighed into a dried, pre-weighed crucible. Each weighed sample in its crucible was placed in a moisture extraction oven at 105 °C and heated for 3 hours. The dried sample was allowed to cool in a desiccator, after which it was reweighed. The process was repeated until a constant weight was obtained. The difference in weight was calculated as a percentage of the original sample weight, and the experiment was replicated twice more.

$$\text{Moisture content (\%)} = [(W_2 - W_3) / W_2] \times 100 \quad (1)$$

Where: W_1 = weight of empty crucible; W_2 = weight of crucible + undried sample; W_3 = weight of crucible + dried sample.

2.4.2. Determination of Protein Content

Total protein was determined by the Kjeldahl method, as described by [AOAC International \(2023\)](#). Five grams (5 g) of each sample was weighed and transferred into a Kjeldahl flask containing boiling chips. A mixture of copper sulphate and sodium sulphate (1 g each) was added to raise the boiling temperature. Twenty millilitres (20 ml) of concentrated H_2SO_4 was added to the flask to assist digestion. The mixture was digested in a fume cupboard until the solution became colourless. It was then cooled to room temperature and transferred quantitatively into a 100 ml volumetric flask, and the digest was made up to volume with water. Twenty millilitres (20 ml) of the digest was pipetted into the distillation flask. Ten millilitres (10 ml) of 2 % boric acid was measured into a receiving beaker, and two drops of methyl red indicator were added. Thirty five millilitres (35 ml) of 40 % NaOH was added to the distillation flask, and the plug was quickly replaced. The mixture was distilled, and the distillate was collected into the boric acid solution. The distillate was titrated against standard 0.1 N HCl until the solution became colourless. A reagent blank was also digested, distilled, and titrated. The experiment was done in triplicate and the average value taken. The percentage nitrogen was calculated and multiplied by a factor of 6.25 to obtain the crude protein content, as follows:

$$\% \text{ Nitrogen} = (T - B) \times (100 \times N \times 14 \times V_f) / (100 \times V_a) \quad (2)$$

Crude protein (%) = % Nitrogen $\times$ 6.25

Where: N = normality of the titrant (HCl = 0.1 N); V_f = total volume of digest (100 ml); T = titre value of sample; B = blank titre value; V_a = aliquot volume distilled.

2.4.3. Determination of fat content (Soxhlet method)

This was done following the method of [AOAC International \(2023\)](#). Five grams (5 g) of each sample was carefully placed in a fat free thimble and covered with cotton wool to prevent sample loss. The loaded thimble was placed in the Soxhlet extractor. Two hundred millilitres (200 ml) of petroleum ether was poured into a preweighed, fat free Soxhlet flask, and the flask was attached to the extractor. The flask was placed on a heating mantle so that the petroleum ether refluxed. Cooling and condensation were achieved using running tap water connected to the

extractor for at least 6 hours, after which the solvent was completely siphoned into the flask. A rotary vacuum evaporator was used to evaporate the solvent, leaving the extracted lipids in the Soxhlet flask. The flask was removed from the evaporator and dried to a constant weight in the oven at 60°C. The flask was cooled in a desiccator and weighed. Each determination was done in triplicate. The amount of fat extracted was calculated using the formula below.

$$\% \text{ Fat} = (\text{weight of extracted lipid} / \text{weight of sample}) \times 100 \quad (3)$$

2.4.4. Determination of Crude Fibre Content

This was determined according to the method of [AOAC International \(2023\)](#). Five grams (5 g) of each sample and 1 g of asbestos were placed in 200 ml of 1.25 % H₂SO₄ and boiled for 30 minutes under reflux; the boiled sample was then washed with hot water. The solution and residue were poured into a Buchner funnel fitted with muslin cloth secured with an elastic band and allowed to filter. The residue was transferred to 200 ml of boiling NaOH and boiled for 30 minutes before being returned to the Buchner funnel for filtration. It was washed twice with alcohol, then thrice with petroleum ether. The resulting residue was placed in a clean, dry crucible and dried in the moisture extraction oven to a constant weight. The dried crucible was removed, cooled, and weighed. The residue was incinerated in a muffle furnace at 600 °C for 2 hours, cooled in a desiccator, and weighed. Each determination was done in triplicate.

$$\% \text{ Crude fibre} = [(W_1 - W_2) / W_3] \times 100 \quad (4)$$

Where: W₁ = weight of sample before incineration; W₂ = weight of sample after incineration; W₃ = weight of original sample.

2.4.5. Determination of Ash Content

This was determined according to the lay down procedure of [AOAC International \(2023\)](#). Five grams (5 g) of each sample was weighed into a crucible, then heated in a moisture extraction oven (Model: Uniscope 9053 Laboratory Oven) for 3 hours at 100 °C. The sample was then transferred into a muffle furnace set at 550 °C until it turned white and free of carbon. The sample was removed from the furnace, cooled in a desiccator to room temperature, and reweighed immediately. The experiment was done in triplicate and the mean taken. The weight of the residual ash was calculated as the ash content.

$$\% \text{ Ash} = (\text{weight of ash} / \text{weight of original sample}) \times 100 \quad (5)$$

2.4.6. Determination of Carbohydrate Content

The percentage of carbohydrate (nitrogen-free extract) was calculated as the difference between 100% and the sum of the percentages of the other measured parameters.

$$\text{Carbohydrate (\%)} = 100 - (\text{protein} + \text{fat} + \text{fibre} + \text{ash} + \text{moisture}) \quad (6)$$

2.5. Pasting Properties of the Composites

The Rapid Visco Analyser (RVA Model 3D, Newport Scientific, Sydney, Australia) was used to determine the pasting properties of the samples. Exactly, 2.5 g of sample was weighed into a dry, empty canister, and 25 ml of distilled water was dispensed into the canister. The mixture was thoroughly stirred and the canister fitted into the RVA as recommended. The slurry was heated from 50 to 95 °C with a holding time of 2 minutes, followed by cooling to 50 °C with a 2-minute holding time. Peak, trough, breakdown, final, and setback viscosities, as well as

peak time and pasting temperature, were read from the pasting profile using Thermocline for Windows software connected to a computer.

2.6. Determination of Functional Properties

2.6.1. Loose Bulk Density

Loose bulk density was determined using the method of [AOAC International \(2023\)](#). Fifty grams (50 g) of composite flour was gently filled into a 100 ml graduated measuring cylinder without compacting. The volume occupied by the flour was recorded. Loose bulk density was calculated as the ratio of the weight of the sample to the volume occupied, expressed in g/ml.

2.6.2. Total (Tapped) Bulk Density

Total bulk density was determined using the method of [AOAC International \(2023\)](#). Fifty grams (50 g) of composite flour was filled into a 100 ml graduated measuring cylinder and tapped gently on a laboratory bench 10-15 times until a constant volume was obtained. The final volume was recorded. Total bulk density was calculated as the ratio of the weight of the sample to the tapped volume, expressed in g/ml.

2.6.3. Water Absorption Capacity (WAC)

The water absorption capacity of the flour blends was determined as described by [Onwuka \(2005\)](#). One gram of sample was weighed into a 20 ml graduated conical centrifuge tube. Using a vortex mixer, the sample was mixed thoroughly with 10 ml of distilled water for 30 seconds. The mixture was allowed to stand for 30 minutes at room temperature and then centrifuged at 500 rpm for 30 minutes. The volume of free water (supernatant) was read directly from the graduated centrifuge tube.

$$\% \text{ WAC} = (\text{weight of water bound} / \text{weight of sample, dry basis}) \times 100 \quad (7)$$

2.6.4. Oil Absorption Capacity (OAC)

One gram of sample was weighed into a 20 ml graduated conical centrifuge tube. Ten millilitres (10 ml) of vegetable oil of known density (0.99 g/ml) was added to the sample, and the mixture was stirred on a magnetic stirrer at 1000 rpm for 5 minutes. The mixture was centrifuged at 3500 rpm for 30 minutes, and the supernatant was removed and measured with a 10 ml measuring cylinder ([Onwuka, 2005](#)). OAC was calculated thus:

$$\text{OAC (g/g)} = \text{volume of oil absorbed} \times \text{density of oil} \times 100 / \text{weight of sample used} \quad (8)$$

2.6.5. Determination of Dispersibility

Dispersibility was determined using the method of [AOAC International \(2023\)](#). Ten grams (10 g) of composite flour was weighed into a 100 ml measuring cylinder, and distilled water was added to a total volume of 100 ml. The mixture was stirred vigorously and allowed to stand undisturbed for 3 hours. The volume of settled particles was recorded. Dispersibility was calculated as the difference between 100 and the volume of settled particles, expressed as a percentage.

2.7. Determination of Antinutrients

2.7.1. Determination of Tannin Content

Tannin content was determined according to the method of [AOAC International \(2023\)](#) with slight modification, as shown below.

$$\text{Tannin content (\%)} = [(V - V_0) \times 0.004157 \times 250 \times 100] / (g \times 25) \quad (9)$$

Where V is the volume of 0.1 N aqueous KMnO₄ used to titrate the sample (ml); V₀ is the volume of 0.1 N aqueous KMnO₄ used to titrate the blank (ml); 0.004157 is the tannin equivalent in 1 ml of 0.1 N aqueous KMnO₄; g is the mass of sample analysed; 250 is the volume of the volumetric flask (ml); and 100 converts the result to a percentage.

2.7.2. Determination of Phytic Acid/Phytate

Phytate was determined using the anion exchange method described by [AOAC International \(2023\)](#). Samples were accurately weighed (1.0-2.0 g) and transferred into 100 ml conical flasks. Fifty millilitres (50 ml) of Na₂SO₄ (100 g/l)-HCl (1.2%) was added. Flasks were capped and shaken vigorously for 2 hours on a rotator at ambient laboratory temperature. The mixture was filtered through Whatman No. 4 filter paper. Ten millilitres (10 ml) of the filtrate was diluted to 30 ml with distilled water after mixing with 1 ml of 0.75 M NaOH, then passed through an anion exchange resin column (resin AG1-X4, 100-200 mesh, Bio-Rad Laboratories; column 0.8 × 10 cm). The column was prewashed with 0.5 M NaCl solution and deionised water. After sample application, the column was washed with 15 ml of distilled water and 20 ml of 0.05 M NaCl solution to remove inorganic phosphate. The retained phytic acid was then eluted with 0.7 M NaCl. The postcolumn reagent was prepared as a 0.03% FeCl₃ solution containing 0.3% sulphosalicylic acid. Four millilitres (4 ml) of the reagent was added to 5 ml of the collected eluate and centrifuged at 3000 rpm for 10 minutes. The absorbance of the supernatant was measured at 500 nm using a spectrophotometer (SECOMAM CE, France). A calibration curve for the colorimetric method was obtained using sodium phytate standards (P-8810, Sigma, USA).

2.7.3. Determination of Oxalate Content

Oxalate was determined using the method of [AOAC International \(2023\)](#). One gram (1 g) of composite flour was weighed into a 100 ml conical flask, 75 ml of 3 mol/L H₂SO₄ was added, and the solution was stirred intermittently with a magnetic stirrer for about 1 hour, then filtered using Whatman No. 1 filter paper. A 25 ml portion of the filtrate was titrated against hot (80-90°C) 0.1 N potassium permanganate (KMnO₄) until a faint pink colour persisted for at least 30 seconds. The oxalate concentration in each sample was obtained from the conversion: 1 ml of 0.1 N permanganate = 0.006303 g oxalate.

2.7.4. Determination of Alkaloid Content

Alkaloids were determined following the method described by [AOAC International \(2023\)](#). One gram (1 g) of composite flour was weighed into a 250 ml beaker, and 40 ml of 10% acetic acid in ethanol was added. The mixture was covered and allowed to stand for 4 hours at room temperature, then filtered using Whatman No. 1 filter paper. The filtrate was concentrated to one quarter of its original volume on a water bath. Concentrated ammonium hydroxide was then added dropwise to the extract until complete precipitation occurred. The precipitate was collected by filtration (Whatman No. 1), washed with dilute ammonium hydroxide, and dried at 60°C. The weight of the dried residue was recorded, and the alkaloid content was calculated as a percentage of the original sample weight.

2.7.5. Determination of Colour Content

Colour content was determined using the method of [AOAC International \(2023\)](#). Each sample (1 g) was weighed into a 100 ml beaker, and 10 ml of distilled water was added to disperse the flour. The mixture was stirred thoroughly and allowed to stand for 10 minutes. The supernatant was decanted and its colour intensity measured using a spectrophotometer at 420 nm. The absorbance value obtained was recorded as the colour content of the sample. Distilled water was used as the blank for calibration.

2.8. Statistical Analysis

Data obtained were analysed using one-way Analysis of Variance (ANOVA), followed by Duncan's Multiple Range Test.

3. RESULTS AND DISCUSSION

3.1. Proximate Composition of Wheat, Unripe Plantain, and Fluted Pumpkin Leaf Composite Flour

Table 2 showed the proximate composition of wheat, unripe plantain, and fluted pumpkin leaf composite flour. Moisture content ranged from 5.89 % (Sample B) to 9.22 % (Sample C), with samples A and D at 9.17 % and 8.41 %, and the differences were significant ($p < 0.05$). The higher moisture content in sample C could be attributed to the drying process undergone by the fluted pumpkin leaf during processing, while the lower moisture content in sample B may be related to the drying method used for the unripe plantain, a finding consistent with [Agoyero, Ezeama, and Abubakar \(2012\)](#). Ash content ranged from 2.22 % (sample A) to 3.54 % (sample C), with samples B and D at 3.53 % and 2.28 %. There was no significant difference ($p > 0.05$) in ash content values between samples B and C, but there was a significant difference between samples A and D. Ash content generally increased with increasing levels of fluted pumpkin leaf, indicating nutrient enhancement, likely due to the significant mineral content of the leaf ([Braide et al., 2012](#)). Fat content ranged from 9.40 % (sample D) to 13.29 % (sample A), with samples B and C at 10.59 % and 13.06 %; the difference among samples was significant ($p < 0.05$). Protein content ranged from 6.59 % (sample C) to 10.91 % (sample A), with samples B and D at 9.22 % and 10.0%. Drying of the unripe plantain contributed considerably to the decrease in protein content of sample B. Fibre content ranged from 1.76% (sample D) to 3.41 % (sample C), with samples A and B at 2.69 % and 2.67 %. Carbohydrate content ranged from 61.73% (sample A) to 68.16% (sample D), with samples B and C at 66.02 % and 64.20 %; the increase in carbohydrate content with a rising proportion of unripe plantain and fluted pumpkin leaf reflects the additional carbohydrate both ingredients contribute on top of that already present in the wheat flour.

Table 2. Proximate composition (%) of wheat, unripe plantain, and fluted pumpkin leaf composite flour.

Sample	Moisture	Ash	Fat	Protein	Fibre	Carbohydrate
A	9.17±0.269 ^a	2.22±0.375 ^b	13.29±0.148 ^a	10.91±0.926 ^a	2.69±0.078 ^b	61.73±1.386 ^c
B	5.89±3.224 ^a	3.53±0.120 ^a	10.59±0.608 ^b	9.22±0.262 ^a	2.67±0.474 ^b	66.02±0.438 ^{ab}
C	9.22±0.262 ^a	3.54±0.431 ^a	13.06±0.226 ^a	6.59±0.658 ^b	3.41±0.148 ^a	64.20±1.725 ^{bc}
D	8.41±0.552 ^a	2.28±0.233 ^b	9.40±0.806 ^b	10.0±0.615 ^a	1.76±0.113 ^c	68.16±0.396 ^a

Note: Values are means ± standard deviation of duplicate determinations. Means with different superscripts in the same column are significantly different ($p < 0.05$). A = 100% wheat flour; B = 90% wheat flour + 10% unripe plantain flour; C = 85% wheat flour + 10% unripe plantain flour + 5% fluted pumpkin leaf powder; D = 80% wheat flour + 10% unripe plantain flour + 10% fluted pumpkin leaf powder.

This pattern, in which partial replacement of wheat flour with a starchy tuber (unripe plantain) and a nutrient dense leafy component (fluted pumpkin leaf) raised ash, fibre, and carbohydrate levels relative to 100% wheat flour, aligns with other studies. [Ochelle, Ikya, Ameh, and Gbaa \(2019\)](#) working with wheat, water yam, and soybean composite bread at substitution levels of up to 25 % water yam and 10 % soybean, similarly reported that increasing

the proportion of non-wheat flour raised the moisture, crude protein, fibre, and ash contents of the composite relative to the 100 % wheat control, while carbohydrate and fat content decreased. Enrichment with a starchy plantain component specifically has also improved the nutrient and antioxidant profile of wheat bread elsewhere, as shown when mature green plantain was combined with amaranth flour in composite bread (Olugbuyi, Adepeju, Ayodele, & Oluwajuyitan, 2023).

3.2. Pasting Properties of Wheat, Unripe Plantain, and Fluted Pumpkin Leaf Composite Flour

The pasting properties of the wheat, unripe plantain, and fluted pumpkin leaf composite flour are presented in Table 3. Peak viscosity ranged from 1777.5 cP (sample B) to 2436.5 cP (sample D), with sample B (90 % wheat + 10% plantain) the lowest and sample D (80% wheat + 10 % plantain + 10 % pumpkin leaf) the highest. Peak viscosity indicates starch swelling and water holding capacity prior to granule breakdown, and the higher value in sample D suggests a greater swelling capacity contributed by the added flours, consistent with the trend reported for composite flours by Igwenyi and Ojimekwe (2017). Trough viscosity ranged from 933.5 cP (sample B) to 1410.5 cP (sample D), reflecting the paste ability to resist thermal and mechanical breakdown during holding; the higher trough value in sample D may be due to the fibrous and protein content contributed by the pumpkin leaf, which could provide structural stability to the paste. Breakdown viscosity ranged between 844 cP (sample B) and 1026 cP (sample D); lower breakdown values indicate greater paste stability, so sample B low value could implied the best resistance to granule rupture among the samples. Final viscosity varied from 2114.5 cP (sample B) to 2718.5 cP (sample A). Final viscosity denotes gel reformation and stability after cooling, and the higher value in sample A suggests a stronger gel network, making it well suited to paste forming applications. Setback viscosity ranged from 1181 cP (sample B) to 1433 cP (sample A); setback relates to starch retrogradation, so the low setback value in sample B could implied reduced retrogradation and potentially longer shelf life. Pasting temperature ranged from 71.88°C (sample D) to 85.20°C (sample B), reflecting the minimum temperature required for gelatinisation; the lower pasting temperature of sample D may imply faster cooking, possibly related to minerals or enzymes contributed by the pumpkin leaf. Peak time spanned 6.00 minutes (sample B) to 6.40 minutes (sample D), with sample B shorter time possibly suggesting potential for more energy efficient processing. These trends broadly agree with reports that incorporating non wheat leafy and starchy components alters the pasting behaviour of composite flours relative to sole wheat flour (Ojo, Olagunju, & Egbekun, 2022). A similar shift in pasting behaviour following non wheat flour incorporation has also been reported for wheat flour blended with amaranth flour, where rheological and baking properties changed progressively with the level of substitution (Singh, Kaur, Mahajan, Singh, & Dhaliwal, 2003).

Table 3. Pasting properties of wheat, unripe plantain, and fluted pumpkin leaf composite flour (cP unless stated).

Sample	Peak	Trough	Breakdown	Final visc.	Setback	Peak time (min)	Past. temp. (°C)
A	2295.5±145.0 ^{ab}	1285.5±133.6 ^{ab}	1010±11.3 ^a	2718.5±139.3 ^a	1433±5.7 ^a	6.13±0.28 ^a	77.05±10.96 ^a
B	1777.5±3.5 ^c	933.5±2.1 ^c	844±1.4 ^b	2114.5±5.0 ^c	1181±2.8 ^d	6.00±0.00 ^a	85.20±0.57 ^a
C	2146.5±79.9 ^b	1123±63.6 ^{bc}	1023.5±16.3 ^a	2448±91.9 ^b	1325±28.3 ^b	6.17±0.05 ^a	85.18±0.53 ^a
D	2436.5±13.4 ^a	1410.5±60.1 ^a	1026±46.7 ^a	2685.5±51.6 ^{ab}	1275±8.5 ^c	6.40±0.09 ^a	71.88±1.20 ^a

Note: Values are means ± standard deviation of duplicate determinations. Means with different superscripts in the same column are significantly different ($p < 0.05$). A = 100% wheat flour; B = 90% wheat flour + 10% unripe plantain flour; C = 85% wheat flour + 10% unripe plantain flour + 5% fluted pumpkin leaf powder; D = 80% wheat flour + 10% unripe plantain flour + 10% fluted pumpkin leaf powder.

3.3. Functional Properties of Wheat, Unripe Plantain, and Fluted Pumpkin Leaf Composite Flour

The functional properties of the wheat, unripe plantain, and fluted pumpkin leaf composite flour are presented in Table 4. Loose bulk density ranged from 0.41 g/ml (sample B) to 0.46 g/ml (sample D), with samples C and A at 0.44 g/ml and 0.43 g/ml, and the differences were significant ($p < 0.05$). Total (tapped) bulk density followed a similar pattern, ranging from 0.70 g/ml (sample B) to 0.75 g/ml (sample D), with samples C and A at 0.72 g/ml and 0.71 g/ml. Water absorption capacity ranged from 0.82 g/g (sample A) to 1.02 g/g (sample C), with samples B and D at 0.97 g/g and 0.95 g/g; the increase in water absorption capacity of the composite flours indicates that they absorbed more water than the sole wheat flour. Oil absorption capacity ranged from 0.99 g/g (sample D) to 1.33 g/g (sample C), with samples B and A both at 1.30 g/g. Dispersibility ranged from 70.0 (sample C) to 75.25 (sample A), with samples D and B at 74.0 and 71.0; all differences among samples were significant ($p < 0.05$). Comparable variability in water and oil absorption capacities with changing blend composition has been reported for other underutilised legume flours, including six *Mucuna* species (Adebowale, Adeyemi, & Oshodi, 2005) and for cassava, rice and pigeon pea composite flours, where retrogradation behaviour and functional properties likewise shifted with blend ratio (Adeyemu, Adebowale, Adegoke, & Sanni, 2014).

Table 4. Functional properties of wheat, unripe plantain, and fluted pumpkin leaf composite flour.

Sample	Loose bulk density (g/ml)	Total bulk density (g/ml)	WAC (g/g)	OAC (g/g)	Dispersibility (%)
A	0.43±0.006 ^{ab}	0.71±0.006 ^{bc}	0.82±0.007 ^c	1.32±0.21 ^a	75.25±1.061 ^a
B	0.41±0.012 ^b	0.70±0.004 ^c	0.97±0.014 ^b	1.30±0.07 ^a	71.0±1.414 ^b
C	0.44±0.008 ^{ab}	0.72±0.004 ^b	1.02±0.035 ^a	1.33±0.035 ^a	70.0±0.000 ^b
D	0.46±0.014 ^a	0.75±0.006 ^a	0.95±0.000 ^b	0.99±0.000 ^b	74.0±0.000 ^a

Note: Values are means ± standard deviation of duplicate determinations. Means with different superscripts in the same column are significantly different ($p < 0.05$). WAC = water absorption capacity; OAC = oil absorption capacity. A = 100% wheat flour; B = 90% wheat flour + 10% unripe plantain flour; C = 85% wheat flour + 10% unripe plantain flour + 5% fluted pumpkin leaf powder; D = 80% wheat flour + 10% unripe plantain flour + 10% fluted pumpkin leaf powder.

3.4. Antinutrient Composition of Wheat, Unripe Plantain, and Fluted Pumpkin Leaf Composite Flour

The antinutrient composition of the wheat, unripe plantain, and fluted pumpkin leaf composite flour is presented in Table 5. Antinutritional factors such as tannins, phytates, oxalates, and alkaloids are naturally occurring plant compounds that can interfere with the digestion and absorption of minerals and other nutrients, although at the low concentrations typical of well processed plant foods they are not considered a significant health hazard, and processing methods such as soaking, drying, and milling generally reduce them further (Samtiya, Aluko, & Dhewa, 2020). Tannin content ranged from 251.50 mg/100g (sample C) to 268.00 mg/100g (sample B). Sample B (90% wheat + 10% unripe plantain) had the highest tannin content, probably due to the polyphenolic content of the plantain flour, while sample C (85 % wheat, 10% plantain, 5% pumpkin leaf) had the lowest, suggesting a dilution effect from the pumpkin leaf, which contains comparatively fewer tannins. Similar increase in tannin content with unripe plantain substitution, and significant differences ($p < 0.05$) across blend proportions, have been reported for other legume and tuber based composite flours (Asoiro, Simeon, Azuka, & Orji, 2022). Phytate content varied between 184.50 mg/100g (sample C) and 190.50 mg/100g (sample B); sample B had the highest phytate content, likely due to the plantain inclusion, while sample C was the lowest, probably due differences in blend ratio. Similar significant variation in phytate content among composite flour blends has also been reported by Asoiro et al. (2022). Oxalate content ranged from 115.32 mg/100g (sample C) to 121.39 mg/100g (sample B). Both the unripe plantain and the pumpkin leaf contribute oxalates, but the levels recorded remain moderate; the lower oxalate content in sample C aligns with its reduced inclusion of these ingredients. Alkaloid content ranged between 55.13 mg/100g (sample C) and 57.99 mg/100g (sample B); the higher level in sample B reflects the alkaloid content

of unripe plantain, while sample C lower value likely stems from the diluting effect of the pumpkin leaf. Overall, the antinutrient levels recorded in all four samples remain within ranges considered safe for human consumption after normal cooking, and are broadly comparable to those reported for other composite flours incorporating unripe plantain and leafy vegetable powders (Asoiro et al., 2022). Extrusion and other thermal processing steps common in composite flour product development have also been shown to lower antinutrient levels further while improving functional properties, reinforcing that the moderate levels recorded here could be reduced even further at the product development stage (Duguma, Forsido, Belachew, & Hensel, 2021).

Table 5. Antinutrient composition of wheat, unripe plantain, and fluted pumpkin leaf composite flour.

Sample	Tannin (mg/100g)	Phytate (mg/100g)	Oxalate (mg/100g)	Alkaloids (mg/100g)
A	262.50	187.50	118.35	56.84
B	268.00	190.50	121.39	57.99
C	251.50	184.50	115.32	55.13
D	255.50	187.50	118.35	56.14

Note: A = 100% wheat flour; B = 90% wheat flour + 10% unripe plantain flour; C = 85% wheat flour + 10% unripe plantain flour + 5% fluted pumpkin leaf powder; D = 80% wheat flour + 10% unripe plantain flour + 10% fluted pumpkin leaf powder.

3.5. Colour Readings of Wheat, Unripe Plantain, and Fluted Pumpkin Leaf Composite Flour

The colour readings of the wheat, unripe plantain, and fluted pumpkin leaf composite flour are presented in Table 6. L values (lightness) ranged from 60.5 to 77.46; Sample A (100% wheat) recorded the highest lightness, while Sample D (80% wheat, 10% plantain, 10% pumpkin leaf) showed the lowest. The reduction in lightness in the enriched blends can be attributed to the natural green pigmentation (chlorophyll) of the fluted pumpkin leaf. This result aligns with Ojo et al. (2022) who reported that including pumpkin leaf reduced L values in composite flours. Lower L values indicate darker flours, which may affect visual appeal in bakery or confectionery applications where a brighter colour is often preferred. The A values (red green axis) of the flour samples ranged from -0.26 to 2.14; Sample D had the lowest (most negative) value, indicating a shift toward green, while Sample A was the reddest, a shift likely due to the chlorophyll content of the pumpkin leaf powder. Ojo et al. (2022) reported a similar green shift in cocoyam pumpkin blends, while Obadina, Olatunde, and Omodara (2021) also observed negative A values in moringa enriched flours. B values (yellow blue axis) ranged from 9.2 to 11.64, with Sample C showing the highest yellowness, likely due to the carotenoid content of the unripe plantain; Sample D had the lowest B value, possibly due to the masking effect of the green pumpkin leaf. Obadina et al. (2021) observed similar increases in B values with plantain flour inclusion. ΔL (change in lightness) ranged from 42.57 to 58.95, with Sample A (the control) recording the highest and Sample D the lowest, again reflecting the strong influence of pumpkin leaf pigmentation. ΔA ranged from -3.83 to -1.45 and ΔB from 7.52 to 10.09; Sample D recorded the most negative ΔA , indicating the greatest shift toward green, while Samples C and A showed higher ΔB , consistent with increased yellowness from the plantain flour. ΔE (total colour difference) ranged from 43.40 to 59.50; the highest ΔE in Sample A suggests it deviated most from the enriched samples, whereas Sample D, with the lowest ΔE , showed the greatest uniformity in pigmentation resulting from the leaf incorporation. These colour shifts confirm that including leafy vegetable powders causes measurable colour transformation, which can influence consumer appeal in products such as noodles or snacks where colour consistency is important.

Table 6. Colour readings of wheat, unripe plantain, and fluted pumpkin leaf composite flour.

Parameter	A	B	C	D
L	77.46±0.324 ^a	65.92±1.216 ^c	72.58±1.729 ^b	60.5±0.538 ^d
A	2.14±0.067 ^a	0.39±0.020 ^b	2.13±0.067 ^a	-0.26±0.026 ^c
B	11.45±0.15 ^a	9.84±0.155 ^b	11.64±0.257 ^a	9.2±0.151 ^c
ΔL	58.95±0.828 ^a	47.99±1.219 ^c	54.66±1.783 ^b	42.57±0.537 ^d
ΔA	-1.61±0.012 ^b	-3.18±0.021 ^c	-1.45±0.064 ^a	-3.83±0.023 ^d
ΔB	10.09±0.273 ^a	8.15±0.161 ^b	9.95±0.254 ^a	7.52±0.151 ^c
ΔE	59.50±0.591 ^a	48.82±1.169 ^c	55.57±1.747 ^b	43.40±0.555 ^d
Note: Values are means ± standard deviation of duplicate determinations. Means with different superscripts in the same row are significantly different (p<0.05). A = 100% wheat flour; B = 90% wheat flour + 10% unripe plantain flour; C = 85% wheat flour + 10% unripe plantain flour + 5% fluted pumpkin leaf powder; D = 80% wheat flour + 10% unripe plantain flour + 10% fluted pumpkin leaf powder.				

4. CONCLUSION AND RECOMMENDATIONS

This study showed that incorporating unripe plantain and fluted pumpkin leaf powder into wheat flour improved its nutritional quality. However, further research is recommended to evaluate the shelf life stability.

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