



PROXIMATE COMPOSITION, MINERAL PROFILE AND SENSORY ANALYSIS OF RIPE AND UNRIPE *Musa paradisiaca* (Linn.)-FORTIFIED BREADS

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Abstract

Minerals, though required in minute quantities for proper growth and development of body tissues, contribute to the optimal functioning of the whole system. Any nutritional strategy that improves the composition, as well as, the proximate value of foods, is a desirable nutritional plan. Therefore, this study comparatively investigated the proximate composition, mineral profile and sensory attributes of ripe and unripe *Musa paradisiaca* (plantain)-fortified breads. Bread dough was prepared following established procedures and fortified with plantain in a ratio of 4:1. The grouping was done as follows; group A - flour bread; group B - ripe plantain-fortified bread; group C - unripe plantain-fortified bread; and Group D - ripe-unripe plantain-fortified bread. The proximate and mineral compositions of the bread samples were determined following standard protocols, while the sensory attributes were evaluated by 30 panelists. Results show that bread fortified with unripe plantain had significantly ($p \leq 0.05$) higher ash and protein contents than the other groups; although, the ash was not significantly higher than that of the ripe plantain-fortified bread. The potassium, phosphorus, calcium and sodium concentrations were also significantly higher than the other bread groups; and the iron and moisture contents were significantly different from that of ripe plantain-fortified bread. However, there was no significant difference in general acceptance between the different fortified-bread and the control bread. This study suggests fortification of bread with unripe plantain as a better nutritional strategy than fortification with ripe plantain. Food fortification with unripe plantain is recommended as a supplement for protein, iron and macro-mineral deficiencies.

Keywords: Bread; Plantain; Fortification; Macro-mineral; Nutritional strategy; Proximate

Introduction

Minerals are bioactive constituents with diverse functionalities and potentials in body's metabolism and homeostasis; they

include potassium, magnesium, sodium, calcium, sulphur, aluminium, chlorine, boron, zinc, iron, copper, iron, etc. They are found in many plants. Minerals are essential

dietary nutrients reported to have diverse biological and metabolic usefulness that include, uptake of glucose, maintenance of normal blood pressure, balance of fluid-electrolyte, formation of bone and teeth, transmission of nerve impulse transmission, regulation of certain enzymes, regulation of parathyroid hormone level, protein synthesis and cellular growth, and reproduction in humans (Gharibzahedi and Jafari, 2017; Byrd-Bredbenner *et al.*, 2019). The inadequate intake and deficiencies of minerals often result to a host of health-related anomalies (Gharibzahedi and Jafari, 2017) and thus, the need to evaluate the levels of minerals in foods for proper guidance towards achieving optimal health for every individual.

Proximate analysis is used to estimate the relative amounts of protein, lipid, water, ash, and carbohydrate in any sample. Proximate composition is one of the nutritional terms usually used to describe feed/food, and means the components of moisture, crude protein, ether extract, crude fiber, crude ash, and nitrogen-free extracts, which are expressed as the content (%) in the sample, respectively. Proximate refers to the analysis of the major nutritional components present in a food or biological sample (Abuengmoh *et al.*, 2022). Protein, lipids, and carbohydrates contribute to the total energy content of an organism, while ash is an inorganic residue that provides insights into the levels of minerals (Ajala *et al.*, 2018). Foods with adequate proximate composition undoubtedly contribute to good health. For instance, crude fiber aids digestion and stimulates the production of useful intestinal bacteria. Soluble crude fiber has also been reported to have important roles in the prevention and treatment of diabetes, atherosclerosis, obesity, etc. (Shaikh *et al.*,

2019). The renewed efforts by researchers, food chemists, nutritionists and dieticians to ensure the populace get and eat varied and balanced diets that will supply good proximate values and essential minerals to the body brought about the emergence of food fortification in the fields of nutrition and food science.

Food fortification is a proven, safe and cost-effective program for improving diets through the addition of proteins, vitamins and minerals (or foods rich in them) to commonly consumed foods during processing so as to increase their nutritional value and prevent or control deficiencies (Olson *et al.*, 2021). According to World Health Organization, "it is a deliberate practice of increasing the content of one or more micronutrients in a food or condiment to improve the nutritional quality of the food supply and provide a public health benefit with minimal risk to health" (WHO, 2024). Food fortification is a nutritional strategy or mechanism of increasing the nutritional content of staple foods and restoration of micronutrient content lost during processing, which has gained widespread recognition. Emaleku *et al.* (2025) recently reported the advantageous nutritional benefits of plantain-fortified chinchin. Although, supplementation of cereal-based foods with plantain, legume, root and tuber for bakery products production to improve nutrient density has been reported (Akubor, 2008) in literatures, there is a dearth of data to support the proximate composition and mineral profile of bread fortified with ripe and unripe plantain blends.

Plantain (*Musa paradisiaca*) is a fruit crop of high importance to Nigerians. The species is known as "Ogede Agbagba" in Yoruba, "Ogadejioke" in Igbo, and "Ayaba" in Hausa (Okechukwu *et al.*, 2022). The fruit pulp or finger of plantain serves as food for man; while the peels serve as feed for animals. Ripe

and unripe plantain possesses high proportion of essential nutrients (minerals and vitamins), antioxidants and other biologically active substances (e.g. phytochemicals) that make them efficacious in the treatment and prevention of some diseases such as diabetes, goiter (Ezeigbo and Ezeigbo, 2018; Maduwanthi and Marapana, 2019). The plant has been reported to be highly rich in dietary fiber, as well as, in iron, zinc, calcium, phosphorus, potassium and sodium with some health benefits (Baiyeri *et al.*, 2011; Borges *et al.*, 2020). The demand for plantain is in the increase in Nigeria and many African countries, and it is a staple food just like bread; and both are well patronized in many parts of the West and Central Africa.

Bread is one of the mostly consumed baked products/foods of wheat flour in Nigeria and many other parts of Africa. It is a leavened food produced through fermentation of wheat flour, that is, a fermented confectionary product produced mainly from wheat flour, water, yeast and salt by a series of operations including mixing, kneading, proofing, shaping and baking (Abuengmoh *et al.*, 2022). Bread is famous for being one of the staple foods of millions of people on a daily basis right from early civilization till date (Abuengmoh *et al.*, 2022). It is reported to contain minerals, mostly magnesium, calcium, and iron. However, it is thought that the mineral and proximate compositions of wheat bread would be more enriched and enhanced if fortified with plantain (ripe and unripe), and would serve as a functional food or supplement for those with nutritional deficiencies. Consequently, this study comparatively evaluated the nutritional composition and sensory characteristics of breads fortified with ripe, and unripe plantain (*Musa paradisiaca*) with the goal that the results would help assist in

counseling the public on the need to fortify bread with plantain for improved nutritional profile.

Materials and Methods

Materials

The materials and ingredients used for this study are Golden Penny prime wheat flour, plantain (*Musa paradisiaca*), Simas margarine, STK royal instant dry yeast, Hollandia evaporated milk, Golden Penny premium white granulated sugar, Havanad active baking soda, assorted gold cinnamon, Dangote salt, and egg. Others include electric blender, baking oven, baking pan, cooking gas cylinder, frying pan, and knife. They were purchased from within Akungba-Akoko market in Ondo State, Nigeria.

Chemicals

The chemicals and reagents used were of analytical grade; and they were obtained from Sigma-Aldrich, USA and BDH, UK. The solutions used were prepared using distilled water obtained from Federal University of Technology, Akure, Ondo State, Nigeria.

Sample collection

Musa paradisiaca (plantain) was bought from Ibaka market, Akungba-Akoko, Ondo State, latitude 7.4740°N and longitude 5.7379°E. The sample was identified, authenticated and assigned voucher specimen code of PSBH 251 by a competent curator at the Herbarium Unit of the Department of Plant Science and Biotechnology, Adekunle Ajasin University Akungba-Akoko, Ondo State, Nigeria. The specimen sample was deposited at the herbarium.

Sample preparations

Fingers of plantain were divided into two parts; one part was left open in a room to reduce exposure to heat and water in order to slow down the ripening processes, while the other part was kept in a tied sack in a room to hasten the ripening processes. Both groups were left for seven days. On the eightieth day, the fingers of plantain left in open remained

unripe and were processed as unripe plantain blend/mash; while those tied in a sack were already ripened and were processed as ripe plantain blend/mash. They were thoroughly washed, peeled, chopped, and blended to a smooth texture to have the different plantain blends; ripe blended plantain, unripe blended plantain, and an equal mixture of ripe and unripe blended plantains.

Similarly, four batches of wheat flour dough were prepared in four different clean bowls by following established bread making procedures reported by Onoja *et al.* (2011). The wheat flour and the other ingredients such as salt, cinnamon, egg, margarine

(butter), evaporated milk, granulated sugar, yeast, and baking soda were measured and mixed together thoroughly. The different plantain blends were then used to fortify the different doughs except the control in the ratio of 4:1; and baked in an oven at 175 °C for 30 minutes to produce the different plantain-fortified breads. The bread samples were packaged in plastic containers and stored at room temperature for a day prior to the proximate and mineral analyses, and the sensory evaluation.

Figures 1 and 2, and Table 1 summarize the preparation procedures and the groupings, with the detailed ingredients used for the study.

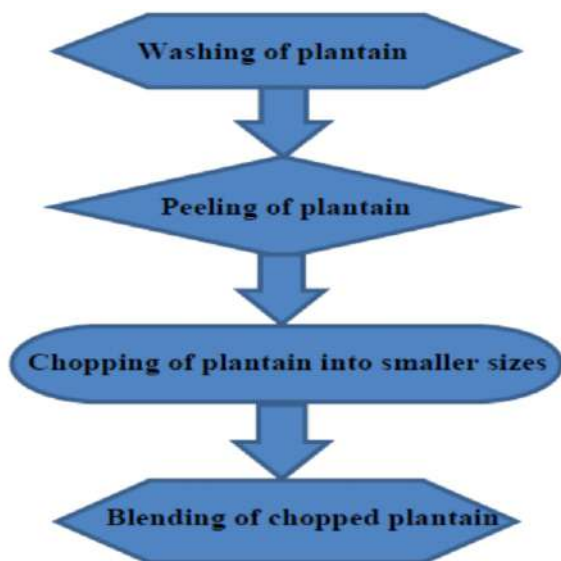


Figure 1a: Processing of plantain into blend/Mash



Figure 1bi: Mashed unripe plantain



Figure 1bii: Mashed ripe plantain

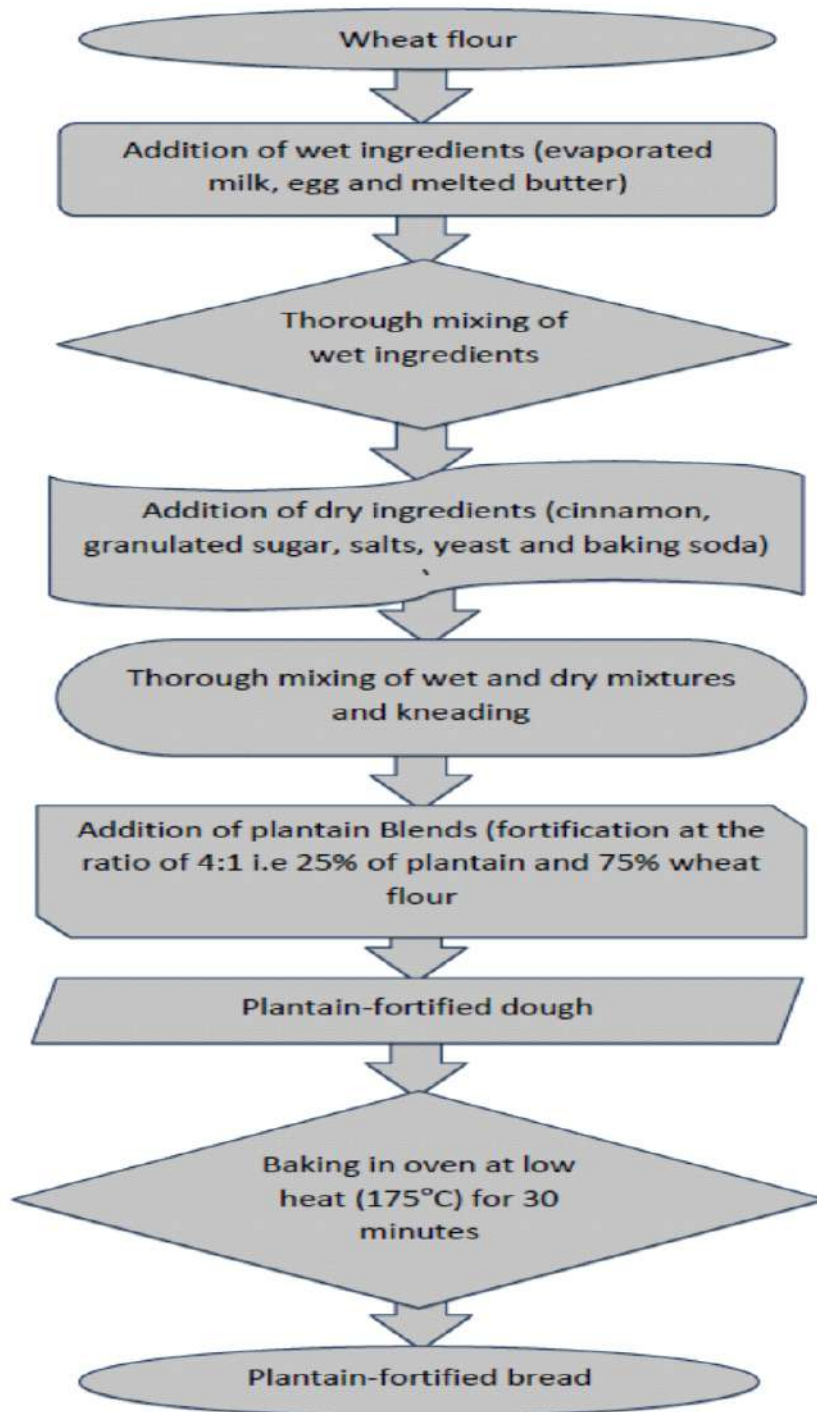


Figure 2: Summary of the processes used for plantain-fortified bread production

Table 1: Groupings and summary of used ingredients

Ingredients (ml)	Group 1	Group 2	Group 3	Group 4
Flour	124	124	124	124
Baking Soda	2.5	2.5	2.5	2.5
Evaporated Milk	44	44	44	44
Margarine	30	30	30	30
Salt	1.25	1.25	1.25	1.25
Granulated Sugar	31.25	31.25	31.25	31.25
Egg	16.25	16.25	16.25	16.25
Cinnamon	2.5	2.5	2.5	2.5
Yeast	2.5	2.5	2.5	2.5
Ripe Plantain	-	31	-	15.5
Unripe Plantain	-	-	31	15.5

Keys: **Group 1** – Wheat Flour Bread (Control); **Group 2** - Ripe Plantain-Fortified Bread; **Group 3** - Unripe Plantain-Fortified Bread; **Group 4** - Ripe and Unripe Plantain-Fortified Bread

Note: Both liquid and powdered ingredients were measured with a small container marked in milliliters (ml). Solid ingredients were grinded into powdered form for convenience and ease of measurement with the container.

Proximate composition

The Association of Official Analytical Chemists' (AOAC, 2014) methods were used to assay for the proximate composition (carbohydrate, moisture, crude fat, ash, crude protein, and crude fiber) of the produced breads. Micro-Kjedahl and soxhlet extraction methods were used to determine the crude protein and fat levels respectively. Protein was determined by the addition of Kjeldahl catalyst tablet and 20 ml of concentrated H₂SO₄ to 1 gram of the sample in the digestion flask, and the flask fixed into the digester at 410 °C for 6 hours until a clear solution was obtained. Boric acid, drops of indicator, distilled water and the digest were mixed in the kjeldahl distillation flask, and 20% NaOH was added. The distillation was for 15 minutes and the distillate titrated against 0.05N HCl with the indicator turning green as the end point. Fat was determined by using filter paper to wrap 1 gram of the sample before being dropped in the receiver of the soxhlet device for the extraction of fat with n-hexane at 60-68°C. The moisture content was determined by weighing 10 grams of the sample into a petri dish and heated to 105°C for 3 hours, and

then cooled for 30 minutes in a dessicator. Crude fiber of the samples was determined by boiling 5 grams of the sample in a successive solution of 1.25% H₂SO₄ and 1.25% NaOH for 30 minutes at a steady temperature using cooling fingers. The sample solution was then filtered, and washed with 1% HCl and distilled water successively. The washing was repeated to get rid of any remnant fat from the sample before being dried in the muffle furnace at 450°C for 2 hours. Total ash was determined by weighing 1 gram of the sample into a clean, pre-weighed crucible and placed in a muffle furnace (550°C) for 3 hours to burn off the carbon in the sample until the sample appeared grey (ash). To get the amount of carbohydrate (nitrogen free extract) in the sample, protein, fat, moisture, ash, and crude fiber values were added together and subtracted from 100.

Mineral Analysis

The atomic absorption spectrometry (AAS) method by the Association of Official Analytical Chemists (AOAC) 2014 described by Adejuwon *et al.* (2021) was used to determine the mineral content in the bread samples. The samples were ashed at 550°C,

dissolved in 10 ml of 0.1 M HCl, and filtered into a volumetric flask. It was made up to 100 ml with distilled water and used to determine the (Fe), zinc (Zn), copper (Cu), calcium (Ca), potassium (K), phosphorous (P) and sodium (Na) concentrations in the samples.

Sensory Evaluation

The method reported by Emaleku *et al.* (2025) was used to evaluate the sensory attributes of the different plantain-fortified breads. The bread samples were coded with three-digit numbers and alphabets, and given to 30 panelists (male and female), comprising of both staff and students of Adekunle Ajasin University, Akungba-

Akoko, Ondo State in the ratio of 1:2 for evaluation. Sensory attributes such as color, crispness, appearance, aroma, smoothness, and overall acceptability were evaluated by the panelists on a 5-point hedonic scale (5 = strongly agree, 4= Agree, 2 = Maybe, 2 = Disagree, and 1 = Strongly disagree). The responses of the panelists were collated and analyzed.

Statistical Analysis

Analysis of Variance (ANOVA) with Turkey Multiple Range Test using was used to analyze the data obtained, using GraphPad software version 5. The level of significant difference was taken at 0.05, which is 95% confidence.

Results

Table 2: Proximate composition of plantain-fortified breads

Proximate (%)	Grouping			
	Group A	Group B	Group C	Group D
Ash	2.28± 0.00 ^a	2.47±0.01 ^{ab}	2.66±0.01 ^b	2.29± 0.00 ^a
Carbohydrates	53.84± 0.10 ^c	50.49±0.02 ^b	50.57±0.03 ^b	46.35±0.09 ^a
Fat	12.11±0.04 ^b	12.42± 0.09 ^b	11.99±0.02 ^b	8.91± 0.70 ^a
Fiber	0.45±0.00 ^b	0.43± 0.02 ^b	0.00±0.00 ^a	0.00±0.00 ^a
Moisture	21.08±0.00 ^a	26.25±0.18 ^b	22.60±0.07 ^a	32.78±0.49 ^c
Protein	10.24±0.09 ^b	8.08±0.01 ^a	12.11±1.07 ^c	9.72±0.00 ^b

Keys: Group A - Flour Bread; **Group B** - Ripe Plantain-Fortified Bread; **Group C** - Unripe Plantain-Fortified Bread; **Group D** - Ripe and Unripe Plantain-Fortified Bread

Data are mean values of triplicate determinations ± standard deviation. Comparison is strictly across columns.

Values not carrying the same superscript letters are significantly different ($p < .05$) from one another, while those carrying same superscript do not differ significantly from one another.

Table 2 results show that unripe plantain-fortified bread had a significantly ($p \leq 0.05$) high protein and ash contents when compared with the other bread groups although; the ash content was not significantly different ($p \geq 0.05$) from that of ripe plantain-fortified bread. The results further show that all plantain-fortified bread groups had significantly low

carbohydrate content when compared with the control bread; and the carbohydrate of unripe plantain-fortified bread, and ripe plantain-fortified bread was not significantly different from each other. Table 2 results also show that unripe plantain-fortified bread and the control bread had significantly low moisture content in comparison with the other plantain-fortified bread groups.

Table 3: Mineral composition of plantain-fortified breads

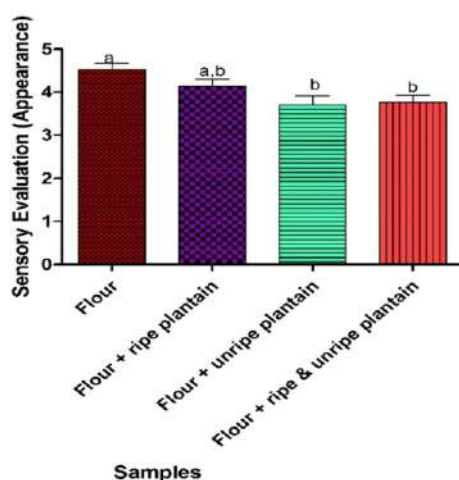
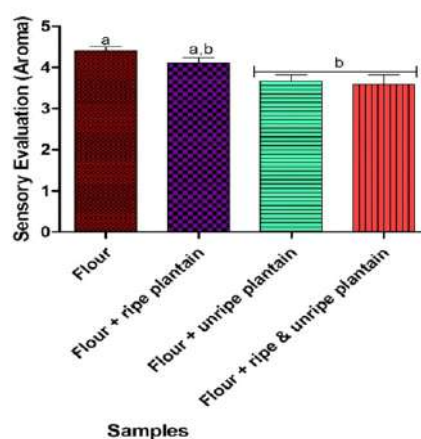
Mineral (mg/100 g)	Grouping			
	Group A	Group B	Group C	Group D
Calcium (Ca)	4.321±0.003 ^c	2.491±0.005 ^a	5.431±0.003 ^d	3.951±0.004 ^b
Phosphorus (P)	18.305±0.005 ^c	14.174±0.135 ^a	21.046±0.004 ^d	16.282±0.005 ^b
Potassium (K)	58.351±0.005 ^b	61.201±0.005 ^c	81.151±0.005 ^d	50.551±0.005 ^a
Sodium (Na)	49.651±0.004 ^b	49.501±0.003 ^b	51.801±0.005 ^c	43.801±0.005 ^a
Copper (Cu)	0.110±0.005 ^b	0.170±0.005 ^c	0.015±0.005 ^a	0.111±0.005 ^b
Iron (Fe)	4.861±0.005 ^d	1.721±0.004 ^b	2.801±0.005 ^c	0.00±0.000 ^a
Zinc (Zn)	2.591±2.005 ^d	2.461±1.995 ^c	0.701±0.005 ^b	0.391±0.005 ^a

Keys: **Group A** - Flour Bread; **Group B** - Ripe Plantain-Fortified Bread; **Group C** - Unripe Plantain-Fortified Bread; **Group D** - Ripe and Unripe Plantain-Fortified Bread

Data are mean values of triplicate determinations ± standard deviation. Comparison is strictly across columns. Values not carrying the same superscript letters are significantly different ($p < .05$) from one another, while those carrying same superscript do not differ significantly from one another.

Table 3 results reveal that minerals such as iron (Fe), zinc (Zn), copper (Cu), calcium (Ca), potassium (P), phosphorous (P) and sodium (Na) are present in the plantain-fortified bread samples at varied concentrations. The results show that unripe plantain-fortified bread had significantly high Ca, P, K, Na and Fe concentrations in comparison with other

bread groups; although, the Fe concentration was significantly low when compared with the control bread. Table iii results also show that unripe plantain-fortified bread has significantly low Cu and Zn concentrations in comparison with other groups; although, the Zn concentration was significantly higher than that of the ripe and unripe plantain-fortified bread group.

**Figure 3: Appearance of plantain-fortified breads****Figure 4: Aroma of plantain-fortified breads**

Legend: Comparison is across bars. Values carrying different alphabets are significantly ($p < 0.05$) from each other, while those carrying the same alphabets are not significantly different from each other.

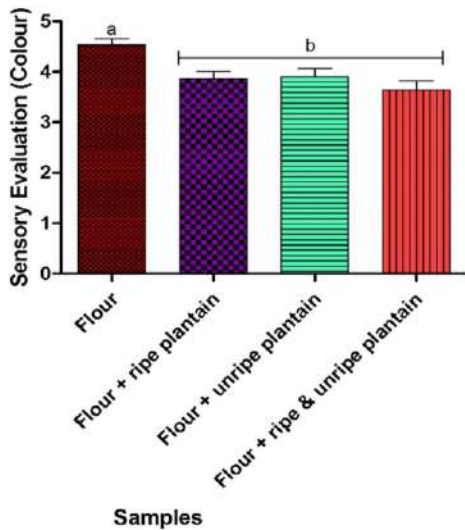


Figure 5: Colour of plantain-fortified breads

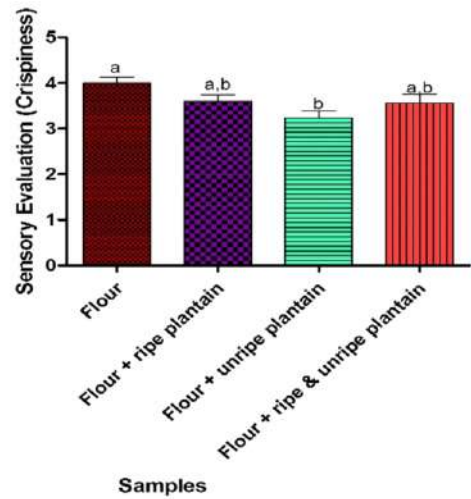


Figure 6: Crispiness of plantain-fortified breads

Legend: Comparison is across bars. Values carrying different alphabets are significantly ($p < 0.05$) from each other, while those carrying the same alphabets are not significantly different from each other.

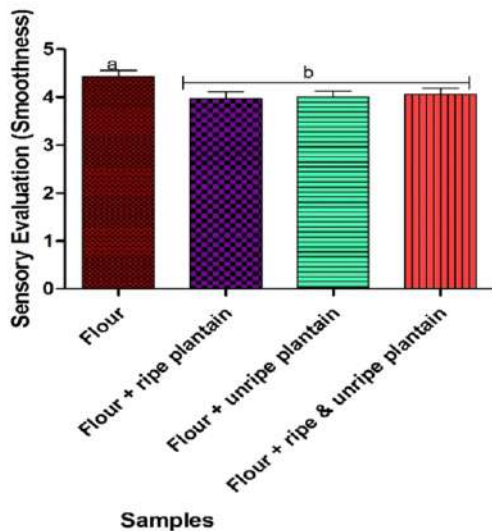


Figure 7: Smoothness of plantain-fortified breads

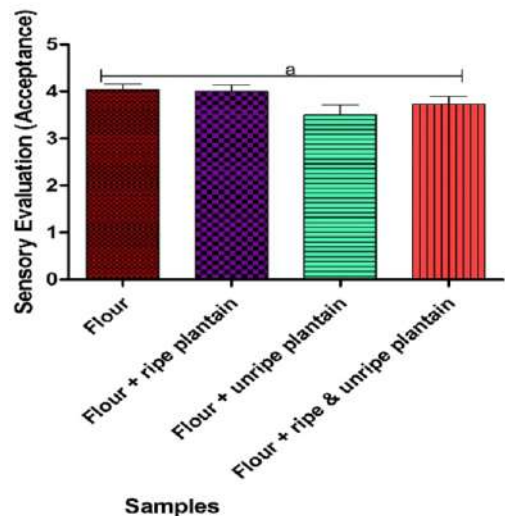


Figure 8: General acceptance of plantain-fortified breads

Legend: Comparison is across bars. Values carrying different alphabets are significantly ($p < 0.05$) from each other, while those carrying the same alphabets are not significantly different from each other.

Figures 3, 4, 5 and 7 results, indicating appearance, aroma, color, and smoothness respectively show that the control bread differed significantly from all the plantain-fortified bread groups in these parameters except, the appearance and aroma of the ripe plantain-fortified bread (Figure 3 and Figure 4 respectively). The results of Figure 6 show that the crispiness of the control bread was not significantly different from all the plantain-fortified bread groups except, the unripe plantain-fortified bread; and there was no significant difference in general acceptance of the different breads as shown in Figure 8 results.

Discussion

Bread, a staple food consumed globally, is constantly being transformed in recent years to meet the diverse nutritional demands of the different teeming population consuming it. The addition of plantain (an unconventional ingredient in bread-making) to wheat flour in this study provides some insightful results that could help meet the nutritional needs of human, and could consequently help improve healthy living. The highly improved protein and ash contents of unripe plantain-fortified bread in comparison with the conventional bread and the other fortified-bread observed in Table 2 suggest, it has a rich source of protein and ash; and that fortification of foods with unripe plantain is a good nutritional strategy that could help address nutritional deficiency in human diets. According to Tognocchi *et al.* (2022), this kind of supplementation would help enhance food nutritional profiles and cater for specific dietary preferences. The increase in protein content could be useful in providing building blocks (amino acids) that are needed for various bodily functions such as muscle development, hormonal regulation, enzyme production among

others functions. Since ash content of a product indicates a rough estimate of its mineral content (Bongjo *et al.*, 2023), the high ash content implies that unripe plantain could be a good source of nutritionally essential minerals and/or trace elements (Abuengmoh *et al.*, 2022; Bongjo *et al.*, 2023). The finding of this study is consistent with the findings of Onoja *et al.* (2011) and Abuengmoh *et al.* (2022) who reported high protein and ash contents when wheat bread was supplemented with legume, root, tuber and plantain flours in different composite forms, and with different percentages of banana and mango flours respectively. The increase in the protein content in this study could be as a result of enzyme hydrolysis of insoluble protein to soluble protein thus, increasing protein availability (Abioye *et al.*, 2020).

Although, the moisture content of all the bread types in this study is less than the maximum quantity of 40% reported by Standard Organization of Nigeria (SON) in 2004 for a food sample (Abuengmoh *et al.*, 2022); the low moisture content of unripe plantain-fortified bread shown in Table 2 in comparison with the other plantain-fortified bread groups, is an indication that it could prevent mould growth, reduce moisture dependent biochemical reactions and be kept naturally safe for a longer period of time (longer shelf life) than the other groups (Ajala *et al.*, 2018). The low moisture content would help to enhance the storage stability of the bread in the same capacity of the control wheat bread. Also, the observed significant low carbohydrate content in all plantain-fortified bread groups in comparison with the control bread group observed in Table 2 is a good nutritional quality for all the plantain-fortified bread groups; and it implies that plantain; most especially the unripe, could be used to mediate carbohydrate associated diseases like diabetes. Ezeigbo and Ezeigbo,

(2018) recommended it for diabetes patients in Nigeria to help manage their condition due to its low carbohydrate and sugar content. The result is also in agreement with Abuengmoh *et al.* (2022) who reported that the addition of banana and mango flours to wheat bread significantly reduced the carbohydrate content. The non-detection of fiber in unripe plantain-fortified bread, and ripe and unripe plantain-fortified bread does not agree with the findings of Onoja *et al.* (2011) and Abuengmoh *et al.* (2022). However, it does not suggest any danger in terms of nutrients since fiber contributes no nutrients to the body. The only little concern is in term of digestion because, fiber adds bulk to food to facilitate bowel movements (peristalsis), which prevents gastrointestinal disorders in human (Grundy *et al.*, 2016).

The significantly high Na, Ca, P and K concentrations and moderately high Fe concentration observed in unripe plantain-fortified bread as shown in Table iii are indications that unripe plantain is rich in these macro-minerals and iron, just as the ash content in Table 2 results suggested. The bread is seen as a potential functional food and good alternative source of these minerals. The result is consistent with the findings of Yarkwan and Uvir (2015), Abuengmoh *et al.* (2022) and Mofunanya *et al.* (2025).

Calcium has crucial role in the development and health of bone and teeth, as well as, healthy cardiovascular system and overall metabolic functions (Barber *et al.*, 2021). Phosphorus promotes healthy bone formation, improves digestion, enhances quick release of energy in the body, and regulates excretion and protein formation in human (Mofunanya *et al.*, 2025). So, the high phosphorus concentration of unripe plantain-fortified bread in this study could serve as compensation for its undetected

fiber in term of digestion. High potassium intake is important for the proper functioning of the nervous system (Barber *et al.*, 2021), while sodium is an essential element for human growth, maintenance of normal cellular homeostasis and regulation of fluid and electrolyte balance and blood pressure (BP) (Strazzullo and Leclercq, 2014; Mofunanya *et al.*, 2025). The higher ratio of potassium concentration (81.151 mg/100 g) to sodium concentration (51.801 mg/100 g) in unripe plantain-fortified as evident in Table 3 further add to the rich nutritional profile. This could make it more suitable for consumption by hypertensive patients (Barber *et al.*, 2021). The higher iron concentration of unripe plantain-fortified bread than the other bread groups is another health-benefiting potential that could be derived from the consumption. This is because iron is a fundamental component of hemoglobin and is responsible for the binding and release (transportation) of oxygen in the blood, support cellular respiration and prevention of anemia (Manish, 2022). It is however important to note that unripe plantain-fortified bread has lower Zn (0.701 mg/100 g) and Cu (0.015 mg/100 g) concentrations than the other bread groups but, their concentrations are not lower beyond what is obtainable in literatures for bread being micronutrients that are needed in just little proportion. To substantiate this, Onoja *et al.* (2011) reported between 0.58 mg/100 g to 0.68 mg/100 g of Zn for their experimental bread, while Barber *et al.* (2021) reported between 0.05 mg/100 g to 2.25 mg/100 g for the same element in their own study. These results confirm that fortification of wheat flour with unripe plantain is effective in improving the nutritional profile of bread, most especially, the macro-minerals.

Although, there are some observable difference in some of the sensory characteristics of the plantain-fortified

bread in comparison with the control bread (see Figures 3 to 7); it however has no detrimental consequence on their acceptability for consumption by the consumers as there is no significant difference in general acceptance between them (see Figure 8). According to Onoja *et al.* (2011), general acceptability of a food product is a function of color, appearance, flavor, texture (smoothness) and taste. Since sensory attributes are essential for understanding consumer preferences, ensuring the palatability of food products, contributing valuable insights to the overall quality and market potential of widely consumed items, the acceptability of plantain-fortified breads by consumers can be said to be guaranteed. These findings are consistent with the reports of Onoja *et al.* (2011); Ajala *et al.* (2018) and Emaleku *et al.* (2025) on sensory characteristics.

Conclusion

Unripe plantain-fortified bread has a richer proximate composition, macro-mineral elements and iron concentration than the control bread (wheat flour), ripe plantain-fortified bread, and ripe and unripe plantain-fortified bread. Moreover, the sensory characteristics of unripe plantain-fortified bread are satisfactory to humans just like the conventional bread and the other plantain-fortified breads. It is therefore recommended as a functional food to tackle some nutritional deficiencies confronting mankind in this present economically-challenged world.

Conflict of Interests

There is no conflict of interest of any kind among authors on this manuscript.

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Authors' Contributions

The study is from the concerted efforts of all listed authors. SAE, CTO and OOA conceived and designed the study. SAE, CTO, OOA, and SOO were involved in the acquisition, analysis and interpretation of data; SAE supervised the research; while all authors, including DOO, GPA, OSJ, ADO and MTS were involved in the original drafting, editing and approval of the manuscript.

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