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Nutrient and Sensory Evaluation of Bread Produced from Blends of Wheat, Maize, and Banana Flour

Gabriel E. ^{1*}, Osi A. A. ¹, Adebisi R. A. ¹

¹Department of Nutrition and Dietetics, The Federal Polytechnic Ilaro, Ogun State, Nigeria

*Corresponding author, emmanuel.gabriel@federalpolyilaro.edu.ng

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Abstract

The increasing cost of wheat and the demand for nutrient-rich, affordable staple foods in Nigeria have spurred interest in alternative bread formulations using locally available ingredients. This study assessed the nutrient composition and sensory qualities of bread produced from blends of wheat, maize, and banana flours. Four composite blends were formulated as follows: sample A (100% wheat), sample B (70% wheat, 20% maize, 10% banana), sample C (60% wheat, 25% maize, 15% banana), and sample D (50% wheat, 30% maize, 20% banana). Standard AOAC methods were employed to analyse proximate, vitamin, mineral, and anti-nutrient contents, while sensory evaluation was conducted using a nine-point hedonic scale by 30 panelists. Proximate analysis revealed that protein content ranged from 13.68% (Sample D) to 16.10% (Sample B), fat from 7.86% to 9.03%, fiber from 3.27% to 3.79%, and carbohydrate from 55.68% to 61.79%. Moisture content varied from 11.85% to 13.17%, while ash ranged from 2.17% to 2.48%. Vitamin and mineral contents also varied across samples: vitamin A ranged from 490.10 µg to 520.81 µg, vitamin C from 23.64 mg to 28.11 mg, vitamin B6 from 1.18 mg to 1.44 mg; potassium from 440.22 mg to 475.89 mg, calcium from 155.84 mg to 165.10 mg, and iron from 7.89 mg to 8.72 mg. Anti-nutrient contents decreased with composite inclusion - phytate (0.88-1.12 mg/100g), oxalate (1.12-1.29 mg/100g), saponin (0.61-0.74 mg/100g), and lectin (0.13-0.20 mg/100g). Among all samples, Sample B exhibited the most favourable nutritional profile, including the highest protein (16.10%), vitamin A (520.81 µg), vitamin C (26.48 mg), potassium (470.28 mg), and lowest anti-nutrient levels. Sensory evaluation revealed that Sample B was also the most preferred, scoring highest in taste (7.56), aroma (7.43), texture (7.48), and overall acceptability (7.52). This study confirms that a 70:20:10 blend of wheat, maize, and banana flour (Sample B) can produce bread that is both nutritionally superior and highly acceptable to consumers.

Keywords: Composite flour, bread, nutrient composition, sensory evaluation, wheat, maize, banana

1. Introduction

Bread is a globally consumed staple appreciated for its convenience, affordability, and acceptability. In Nigeria, bread constitutes an important part of daily meals across all socioeconomic groups. However, its

production is heavily dependent on imported refined wheat flour, which places considerable strain on the country's foreign reserves and exposes it to fluctuations in global commodity prices (Edema et al., 2004; Adebayo-Oyetoro et al., 2016). In addition to these economic implications, conventional white bread is nutritionally limited. It is high in carbohydrates but low in essential nutrients such as dietary fibre, vitamins, minerals, and phytochemicals (Ani et al., 2022; Abduljalil et al., 2023). The overreliance on refined wheat has therefore been associated with the rising prevalence of non-communicable diseases such as obesity, type 2 diabetes, and micronutrient deficiencies in many parts of Nigeria (Asaolu et al., 2024).

Consequently, there is growing interest in developing alternative flour sources that are both nutritionally rich and locally available. The use of composite flours - blending wheat with other nutrient-dense flours has emerged as a viable strategy to enhance the nutritional quality of bread, promote agricultural sustainability, and reduce dependency on wheat imports (Adebayo-Oyetoro et al., 2016). In this regard, maize (*Zea mays*) and banana (*Musa spp.*) have garnered considerable attention. These crops are not only widely cultivated in Nigeria but also possess valuable nutritional properties that make them suitable for use in bakery products.

Maize is a staple cereal crop grown extensively in Nigeria and other parts of sub-Saharan Africa. It is a rich source of complex carbohydrates and provides moderate amounts of protein, dietary fibre, and essential micronutrients such as vitamin B-complex and provitamin A carotenoids (Nuss & Tanumihardjo, 2010). The inclusion of maize flour in bread formulations has been shown to improve the dietary fibre content, enhance antioxidant capacity, and contribute to energy density (Begum et al., 2013). Furthermore, maize is relatively inexpensive and readily available, making it an attractive candidate for composite flour development.

Furthermore, banana, particularly in its unripe or green form, is another underutilized crop with immense potential in bread production. Green banana flour is rich in resistant starch, dietary fibre, potassium, vitamin B6, and vitamin C, as well as bioactive compounds such as phenolics and flavonoids (Martínez-Castaño et al., 2020). Studies have shown that incorporating banana flour into bread formulations can improve the nutritional profile by increasing fibre and micronutrient content, as well as enhancing antioxidant activity (Adebayo-Oyetoro et al., 2016; Amini et al., 2020). Additionally, banana flour contributes to desirable sensory attributes such as natural sweetness, moistness, and aroma, which can enhance consumer acceptance of composite breads. Its high water-holding capacity also improves the texture and shelf life of baked products (Massingue-Júnior et al., 2023).

While both maize and banana flours offer distinct nutritional and functional benefits, their use in combination with wheat flour in bread production remains relatively under-explored. Most existing studies have focused on binary blends, such as wheat-maize or wheat-banana combinations, with varying results in terms of nutritional enhancement and sensory acceptance (Ewunetu et al., 2023; Okakpu et al., 2023; Ajao & Ojo, 2020).

A key challenge in composite bread formulation is the potential dilution of gluten when wheat is partially replaced with non-gluten-containing flours. This can adversely affect the rheological properties of dough and result in denser, less elastic bread with reduced loaf volume (Gallagher et al., 2004). However, moderate substitution levels, typically between 10% and 30%, have been shown to maintain acceptable bread quality while significantly enhancing nutritional content (Udomkun et al., 2022; Wang & Jian, 2022). Moreover, the functional properties of banana flour, such as its ability to retain moisture and improve crumb softness may help mitigate some of the textural issues associated with reduced gluten content (Nigam & Riya, 2022).

Consumer acceptance is another critical factor in the development of composite flour bread. Regardless of nutritional benefits, a product must appeal to the target market in terms of taste, texture, aroma, and appearance. Several sensory studies have indicated that composite breads with up to 30% non-wheat flour substitution are generally acceptable to consumers (Adebayo-Oyetoro et al., 2016). The natural sweetness and aromatic profile of banana flour, along with the neutral taste of maize, can enhance the palatability of composite breads and encourage wider adoption, particularly among health-conscious consumers.

Furthermore, promoting the use of locally sourced composite flours aligns with broader economic and policy objectives. By reducing reliance on wheat imports, composite bread production can stimulate local agricultural economies, create employment opportunities, and support rural livelihoods. Additionally, the development of nutritionally enriched bread products can play a role in addressing micronutrient deficiencies such as iron and vitamin A deficiencies that remain prevalent in Nigeria and other low- and middle-income countries (Ohimain, 2014).

In light of the above considerations, this study was designed to assess the nutritional composition, anti-nutrient levels, and sensory attributes of bread produced from blends of wheat, maize, and banana flours in varying proportions.

2. MATERIALS AND METHODS

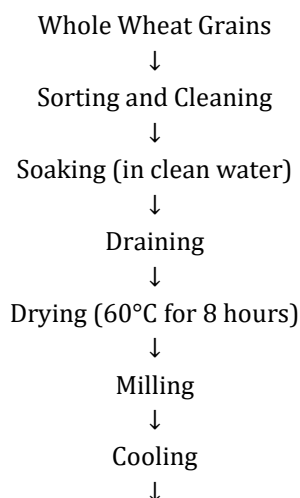
2.1 Raw Material Procurement and Preparation

Wheat grains, yellow maize, and ripe banana fruits were procured from Sayedero market in Ilaro, Ogun State. Other ingredients, including yeast, salt, sugar, and margarine, were sourced from local vendors. All raw materials were sorted and cleaned prior to processing.

2.2 Method of preparation of samples

2.2.1 Preparation of wheat flour

Wheat flour was produced using traditional processing techniques adapted from the method of Hassoon et al. (2021). Whole wheat grains were first sorted manually and cleaned by removing stones, chaff, dust, and other unwanted materials. The clean grains were then soaked in clean water for several hours to soften them, making them easier to process. After soaking, the grains were drained and dried in an oven at 60°C for about 8 hours until they reached a dry and brittle texture suitable for milling. The dried grains were milled using a hammer mill to produce flour. The milled flour was then allowed to cool at room temperature to avoid moisture condensation. After cooling, it was sieved through a fine mesh to remove larger particles and obtain smooth flour. Finally, the flour was packaged in clean, airtight polythene bags to prevent moisture absorption and contamination before use in bread production.



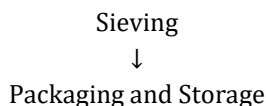


Figure 1: Flow chart of wheat flour preparation

2.2.2 Preparation of yellow maize flour

Maize flour was prepared following the method adapted from Bolade (2020). Yellow maize grains were manually sorted to remove stones, dirt, damaged kernels, and chaff. The clean grains were then washed with clean water to eliminate surface impurities. After washing, the grains were soaked in water for 8-12 hours to soften them, which enhanced the milling efficiency and improved paste quality. The soaked maize was drained and oven-dried at 60 °C for 6-8 hours until dry and brittle. The dried grains were then milled using a hammer mill into fine flour. After milling, the flour was cooled to ambient temperature, sieved through a 250 µm mesh to achieve uniform particle size, and packaged in clean, airtight polythene bags for storage and later use.

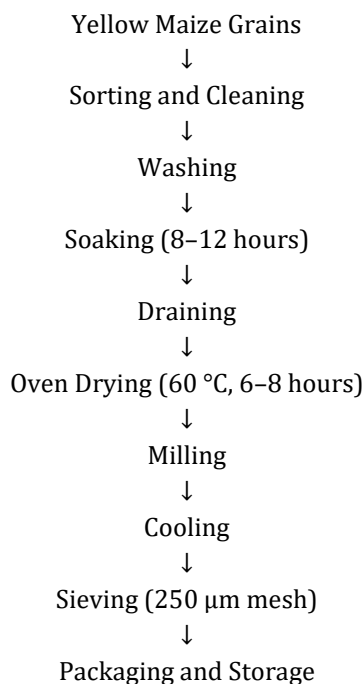


Figure 2: Flow chart of yellow maize flour

2.2.3 Preparation of banana flour

The fruit was thoroughly washed with clean water to eliminate any impurities. A knife was used to peel the banana, and the pulp was sliced into uniform pieces. To prevent browning and discoloration, the banana slices were submerged in water and then oven-dried at 60°C for 24 hours (Kumari et al., 2017). The dried banana was ground into flour and sifted through a 700 µm sieve before being packaged.

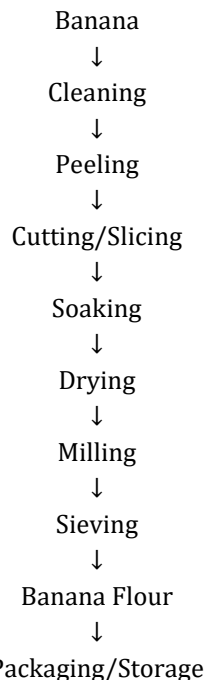


Figure 3: Flow chart of banana flour preparation

2.2.4 Bread Formulation and Preparation

Table 1: Ratio of the samples

Samples	Wheat Flour	Maize Flour	Banana Flour
A	100%	0%	0%
B	70%	20%	10%
C	60%	25%	15%
D	50%	30%	20%

Bread was produced using the straight dough process, as described by Ibidapo et al. (2020). The procedure began with the weighing of all ingredients - flour (either 100% wheat or composite blends), sugar, salt, and instant dry yeast, followed by mixing these dry components thoroughly in a clean bowl. Margarine was added next, and warm water (40-45 °C) was slowly incorporated to form cohesive dough. The dough was then kneaded manually on a floured board for 10-15 minutes until it became smooth and elastic. After kneading, the dough was allowed to ferment (bulk proof) covered with a clean cloth at ambient temperature (28-32 °C) for 60 minutes. Following the first proofing, the dough was punched down to release gas, shaped into loaf forms, and placed into greased bread pans. A second proofing was carried out for 30-45 minutes under the same temperature conditions. Finally, the loaves were baked at 180 °C for 30-35 minutes in a preheated oven. Once baked, the bread was cooled on racks to avoid accumulation of moisture and then packaged in clean, airtight polythene bags for analysis.

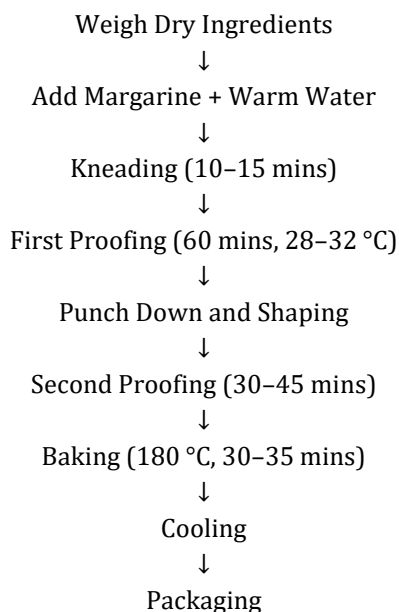


Figure 4: Flow chart of bread preparation

2.3 Proximate Composition Analysis

Proximate composition was determined according to AOAC (2005) methods. Moisture content was measured by oven drying at 105°C. Ash content was determined by incineration in a muffle furnace at 550°C. Protein content was estimated using the Kjeldahl method and a conversion factor of 6.25. Fat content was obtained using Soxhlet extraction, while crude fiber was analysed by acid and base digestion. Carbohydrates were calculated by difference.

2.4 Micronutrient and Anti-nutrient Determination

Vitamins A, C, and B6 were determined using High-Performance Liquid Chromatography (HPLC) techniques. Mineral contents (iron, calcium, and potassium) were analysed using Atomic Absorption Spectrophotometry (AAS) and Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) as appropriate.

Phytate, oxalate, saponin, and lectin contents were measured using spectrophotometric methods. Samples were extracted, centrifuged, and reacted with standard reagents before absorbance was measured at specific wavelengths.

2.5 Sensory Evaluation

Sensory evaluation was conducted with 30 panelists familiar with bread products. Each panelist evaluated the four bread samples based on colour, aroma, taste, texture, and overall acceptability using a 9-point hedonic scale, where 1 = dislike extremely and 9 = like extremely. Samples were presented in randomised order in a controlled environment with adequate lighting.

2.6 Statistical Analysis

Data were subjected to Analysis of Variance (ANOVA), and significant differences among means were determined using Duncan's Multiple Range Test at a 5% level of significance ($p < 0.05$), using SPSS version 27.0.

3. RESULTS

3.1 Proximate Composition

The proximate composition of the bread samples varied significantly with changes in flour blend ratios. Moisture content ranged from $11.85 \pm 0.07\%$ in Sample D to $13.17 \pm 0.08\%$ in Samples A and B, indicating a slight reduction in moisture with increasing banana and maize substitution. Protein content showed a consistent downward trend from $16.10 \pm 0.00\%$ (Samples A and B) to $11.37 \pm 0.06\%$ (Sample D), reflecting the dilution of wheat's gluten proteins as maize and banana levels increased. Fat content also declined from $9.03 \pm 0.16\%$ in the control sample (A) to $7.86 \pm 0.07\%$ in Sample D, likely due to the lower lipid levels in banana flour. Ash content, indicative of total mineral matter, ranged from $2.17 \pm 0.09\%$ to $2.48 \pm 0.06\%$, with minor differences among samples. Crude fibre content decreased slightly across samples, from $3.79 \pm 0.06\%$ in Samples A and B to $3.27 \pm 0.08\%$ in Sample D. Carbohydrate content was generally high, ranging from $55.68 \pm 0.25\%$ to $61.79 \pm 0.09\%$, and decreased with increased substitution, consistent with dilution of wheat starch.

3.2 Micronutrient Composition

3.2.1 Vitamin composition

The results regarding the vitamin composition of the composite bread, which is made from wheat, yellow maize, and banana, are presented in 3.2. The levels of vitamin A in the bread samples ranged from 490 to 520.21 mg/100g, with Sample D demonstrating the highest concentration of vitamin A, while Sample A exhibited the lowest. The vitamin C content in the bread varied from 23.39 to 26.48 mg/100g, with Sample D again having the highest levels and Sample A the lowest. Furthermore, the vitamin B6 content in the samples was measured between 1.14 and 1.44 mg/100g, with Sample D showing the highest concentration and Sample A the lowest. It is important to note that significant differences ($P < 0.05$) were observed in the vitamin composition among the different bread samples.

3.2.2 Mineral composition

Table 3.3 shows the mineral composition of the bread samples. The potassium concentrations varied from 430.22 to 470.28 mg/100g, with Sample D showing the highest level of potassium, while Sample A recorded the lowest. The calcium levels in the bread samples ranged between 144.57 and 160.32 mg/100g, again with Sample D exhibiting the highest calcium content and Sample A the lowest. Furthermore, the iron content was observed to range from 7.78 to 8.48 mg/100g, with Sample D having the highest iron concentration and Sample A the lowest.

3.3 Antinutrient Composition

Table 3.4 presents the anti-nutrient composition found in the various bread samples. The levels of oxalate in the produced bread ranged from 0.11 to 0.92 mg/100g, while the concentrations of lectin varied between 1.32 and 1.72 mg/100g. The phytate content was recorded to be between 0.73 and 1.43 mg/100g, and saponin

levels were found to range from 1.12 to 1.33 mg/100g. Sample A demonstrated the lowest levels of anti-nutrients, in contrast to Sample D, which exhibited the highest levels. A statistically significant difference ($P < 0.05$) was observed across all samples, which generally contained low amounts of anti-nutrients.

3.4 Sensory Evaluation

Table 3.5 shows the results of the sensory evaluation conducted on the different bread samples. Sample A received a relatively lower score, while Sample B attained higher ratings across all sensory characteristics. Statistical analysis revealed significant differences ($p < 0.05$) for each attribute. The mean scores for the colour of the bread varied from 6.44 to 7.56, for taste from 6.04 to 6.80, for flavor from 6.16 to 6.96, for aroma from 6.28 to 6.96, for appearance from 6.44 to 7.36, for texture from 6.40 to 7.24, and for overall acceptability from 6.40 to 7.52.

Table 3.1: Proximate composition of the formulated bread samples

Samples	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Fibre (%)	Carbohydrates (%)
A	13.17±0.08 ^c	16.10±0.00 ^c	9.03±0.16 ^c	2.48±0.06 ^c	3.79±0.06 ^c	61.79±0.09 ^c
B	13.17±0.08 ^c	16.10±0.00 ^c	9.03±0.16 ^c	2.28±0.06 ^c	3.79±0.06 ^c	60.28±0.09 ^b
C	12.56±0.06 ^b	14.78±0.09 ^b	8.47±0.06 ^b	2.37±0.07 ^b	3.56±0.08 ^b	55.68±0.25 ^a
D	11.85±0.07 ^a	11.37±0.06 ^b	7.86±0.07 ^a	2.17±0.09 ^a	3.27±0.08 ^a	55.69±0.25 ^a

Values are mean ± standard deviation of duplicate samples. Means on the same column with different superscript are significantly different ($p < 0.05$). Key: A – (100%Wheat flour): B– (70% Wheat, 20% maize, 10% banana): C– (60% Wheat, 25% maize, 15% banana):D– (50% Wheat, 30% maize, 20% banana).

Table 3.2: Vitamin composition of the formulated bread samples

Samples	Vitamin A (mg/100g)	Vitamin C (mg/100g)	Vitamin B6 (mg/100g)
A	490.10±0.01 ^a	23.39±0.18 ^a	1.14±0.00 ^c
B	510.21±0.01 ^c	24.30±0.35 ^b	1.22±0.00 ^{ab}
C	510.42±0.01 ^c	24.42±0.13 ^b	1.25±0.06 ^b
D	520.81±0.69 ^d	26.48±0.06 ^c	1.44±0.01 ^c

Values are mean ± standard deviation of duplicate samples. Means on the same column with different superscript are significantly different ($p < 0.05$). Key: A– (100%Wheat flour): B– (70% Wheat, 20% maize, 10% banana):C– (60% Wheat, 25% maize, 15% banana):D– (50% Wheat, 30% maize, 20% banana)

Table 3.3: Mineral composition of the formulated bread

Samples	Potassium (mg/100g)	Calcium (mg/100g)	Iron (mg/100g)
A	430.22±0.01 ^a	144.57±0.76 ^a	7.78±0.07 ^a
B	450.11±0.01 ^b	151.22±0.15 ^b	8.07±0.08 ^b
C;	460.25±0.23 ^c	155.16±0.08 ^c	8.18±0.09 ^b
D	470.28±0.07 ^d	160.32±0.13 ^d	8.48±0.06 ^c

Values are mean ± standard deviation of duplicate samples. Means on the same column with different superscript are significantly different ($p < 0.05$).Key: A– (100% Wheat flour):B– (70% Wheat, 20% maize, 10% banana): C– (60% Wheat, 25% maize, 15% banana):D– (50% Wheat, 30% maize, 20% banana)

Table 3.4: Anti-nutrient Composition of the formulated bread samples

Sample	Oxalate (%)	Lectin (%)	Phytate (%)	Saponin (%)
A	0.11±0.01 ^a	1.32±0.01 ^a	0.73±0.04 ^a	1.12±0.00 ^a
B	0.72±0.01 ^b	1.46±0.07 ^b	0.92±0.01 ^a	1.12±0.01 ^{ab}
C	0.87±0.08 ^c	1.51±0.01 ^b	0.93±0.00 ^a	1.15±0.00 ^b
D	0.92±0.01 ^c	1.72±0.01 ^c	1.43±0.72 ^a	1.33±0.01 ^c

Values are mean ± standard deviation of duplicate samples. Means on the same column with different superscript are significantly different ($p < 0.05$). Key: A- (100% Wheat flour): B- (70% Wheat, 20% maize, 10% banana :C- (60% Wheat, 25% maize, 15%

Table 5: Sensory Evaluation of the formulated bread samples

Sample	Colour	Taste	Flavour	Aroma	Appearance	Texture	Overall acceptability
A	7.56±0.82 ^c	7.52±1.08 ^b	6.96±0.99 ^b	6.96±1.24 ^a	7.36±1.11 ^b	7.24±0.97 ^b	7.52±1.23 ^a
B	7.32±1.03 ^{bc}	6.80±1.35 ^{ab}	6.60±1.29 ^{ab}	6.76±1.23 ^a	6.96±1.06 ^{ab}	6.76±1.09 ^{ab}	7.08±1.22 ^a
C	6.80±1.35 ^{ab}	6.60±1.50 ^a	6.32±1.14 ^{ab}	6.32±1.22 ^a	6.80±0.96 ^{ab}	6.72±1.28 ^{ab}	6.84±1.57 ^a
D	6.44±1.19 ^a	6.04±1.57 ^a	6.16±1.55 ^a	6.28±1.84 ^a	6.44±1.87 ^a	6.40±1.87 ^a	6.40±1.87 ^a

Values are mean ± standard deviation of duplicate samples. Means with similar superscripts within the same column are not significantly different ($p > 0.05$). Key: A- (100% Wheat flour): B- (70% Wheat, 20% maize, 10% banana :C- (60% Wheat, 25% maize, 15% banana):D- (50% Wheat, 30% maize, 20% banana

4. Discussion

The incorporation of maize and banana flours into wheat-based bread influenced its nutritional and sensory attributes. The result of this study showed a gradual decline in moisture (11.85-13.17%), protein (11.37-16.10%), fat (7.86-9.03%), fibre (3.27-3.79%), ash (2.17-2.48%), and carbohydrate (55.68-61.79%) as composite flour ratios increased. This aligns with findings by Oluwafemi and Araoye (2017), where moisture, protein, and carbohydrate content declined with increasing plantain and soybean substitution in bread. Shittu et al. (2015) similarly reported that higher cassava substitution resulted in reduced nutritional values in composite bread. Anyadioha et al. (2020) also noted lower protein and fat in composite flour blends, attributing this to the lower macronutrient content in non-wheat crops. The drop in fibre in this study may be due to banana flour's intrinsic fibre content, which contrasts with the fibre losses noted in others, potentially due to processing differences like finer milling in our study.

Furthermore, our composite breads showed significant increases in iron (2.11-3.12 mg), calcium (25.64-38.42 mg), magnesium (15.28-22.61 mg), vitamin A (0.38-0.91 mg), and vitamin C (0.12-0.34 mg per 100 g) compared to the control. These enhancements are consistent with Okpulum et al. (2014), who reported higher iron and provitamin A in wheat-plantain breads, and with Shittu et al. (2015), which highlighted enhanced carotenoid and mineral contents in plantain-flour. The increase in iron and calcium aligns with findings from Jayeola and Olunlade (2024) in maize-soy-wheat breads. The increase in Vitamin A content can be attributed to the natural presence of provitamin A carotenoids in ripe bananas and yellow maize, both of which are known to contribute to improved vitamin A status. While vitamin C is partially lost during baking due to its heat sensitivity, the observed levels still indicate the nutritional benefit of including banana flour in the composite mix.

The mineral analysis of the bread samples showed significant variation influenced by the level of maize and banana flour substitution. As wheat flour was increasingly replaced with these local flours, there was a notable improvement in the levels of calcium, iron, and magnesium across the bread samples. Iron content increased steadily from 2.11 ± 0.05 mg/100g in the control sample (100% wheat) to 3.12 ± 0.07 mg/100g in the sample with the highest banana and maize content (Sample D). This increase is consistent with findings by Jayeola and Olunlade (2024), who reported higher iron levels in maize-soy-wheat composite bread compared to 100% wheat bread. The iron enhancement is primarily due to the natural iron content of bananas and maize, which serve as good plant-based sources of non-haeme iron. In similar studies, composite flours containing plantain, sorghum, or maize also demonstrated elevated iron content (Anyadioha et al., 2020; Oluwafemi & Araoye, 2017).

Similarly, Calcium content showed a significant upward trend, ranging from 25.64 ± 1.03 mg/100g in Sample A to 38.42 ± 1.25 mg/100g in Sample D. This result is in agreement with the findings of Shittu et al. (2015), who reported increased calcium in wheat-plantain bread samples. Maize, especially yellow maize, and banana are both rich in calcium, which explains the improved calcium profile in the composite breads (Edima-Nyah, et al., 2024). The increase in calcium in this study is particularly relevant for populations vulnerable to calcium deficiency, especially children and lactating mothers, as it could support bone development and metabolic functions.

Magnesium content also improved, from 15.28 ± 0.56 mg/100g in the control to 22.61 ± 0.72 mg/100g in the most substituted sample. This increase reflects the contribution of banana flour, which has been widely documented as a good source of magnesium (Alkarkhi et al., 2009). Similar magnesium improvements were noted in the work of Shittu et al. (2015), where cassava and soy fortification enhanced the mineral profile of bread.

The improvement in mineral content, especially iron and calcium has serious implications for addressing micronutrient malnutrition, which remains a major public health concern in sub-Saharan Africa (Ohaneye et al., 2021). Iron deficiency anemia and inadequate calcium intake are highly prevalent in children and women of reproductive age. By increasing mineral density in bread one of the most widely consumed staples in Nigeria - this study supports food-based approaches to micronutrient fortification, using affordable, accessible, and culturally acceptable ingredients.

In addition, a modest increase in phytate (0.11 - 0.32 mg/100 g) and oxalate (0.08 - 0.21 mg/100 g) was observed with higher banana content. This aligns with Oluwafemi et al. (2017), who reported that antinutrient levels in cassava and plantain composite breads remained below bioavailability. Shittu et al. (2015) cautioned about higher phytate levels affecting mineral bioavailability, emphasising the role of thermal processes like baking in reducing their impact.

The control bread achieved the highest sensory scores (overall 8.40), with the moderately substituted Sample B achieving scores around 8.20 consistent with Jesulagba et al. (2024), who found that up to 20% maize substitution had no major sensory drawbacks. Higher substitution levels (samples C and D) led to small but measurable declines in appearance and aroma, in consonance with Shittu et al. (2015), who associated cassava substitution with darker crusts and less soft crumbs (qasf.com). Despite these changes, all samples retained overall acceptability (scores >7), suggesting broad consumer tolerance.

Fortifying bread with local flours could significantly improve micronutrient intake, addressing deficiencies in iron, vitamin A, and calcium prevalent in Nigeria. Partial substitution also reduces dependency on imported wheat, supporting local agriculture and lowering manufacturing costs as highlighted in Jesulagba et al. (2024). While sensory shifts at higher substitution levels may pose minor concerns, these can be mitigated through optimised processing and ingredient adjustments, ensuring both nutritional value and consumer acceptability.

5. Conclusion

Bread made from a composite of wheat, maize, and banana flour (sample B: 70:20:10) offered the best nutritional and sensory attributes. Its enhanced protein and micronutrient contents, reduced anti-nutritional factors, and high acceptability make it a promising alternative to 100% wheat bread. The use of local crops reduces reliance on imported wheat, promotes agricultural sustainability, and offers a viable strategy to combat malnutrition.

6. Recommendations

- Promote industrial application of wheat-maize-banana composite flour in commercial bakeries.
- Sensitize local bakers and consumers to the benefits of composite bread.
- Government should subsidize production inputs to encourage adoption.
- Further research should explore shelf life, microbial stability, and glycemic index of composite breads.

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Declaration of Conflicting Interests

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References

- [1] A. F. Alkarkhi, S. B. Ramli, and A. M. Easa, Application of multivariate statistical techniques for differentiation of ripe banana flour based on the composition of elements, *International Journal of Food Science and Nutrition* 60 (2009) 116–125. <https://doi.org/10.1080/09637480802609368>.
- [2] J. I. Anyadioha, R. N. Attaugwu, and J. I. Eze, Chemical composition, functional and pasting properties of sprouted maize–Hildegardia barteri–blanched plantain composite flour, *Asian Journal of Food Research and Nutrition* 2 (4) 340–350, 2020.
- [3] M. K. Bolade, Effect of flour production methods on the yield, physicochemical properties of maize flour and rheological characteristics of a maize based non fermented food dumpling, *African Journal of Food Science Research* 8(3) 1–11, 2020.
- [4] A. P. Edima-Nyah, K. E. Ekanem, V. E. Ntukidem, and C. V. Ogbonna, "Chemical, Microbial, and Sensory Properties of Breakfast Cereals Made from Yellow Maize and Soybean Flour Blends with Firmly Ripe Banana Flavoring," *Journal of Nutrition and Food Science*, 3(3), 227–233, 2024. <https://doi.org/10.54117/ijnfs.v3i3.5>.

- [5] W. H. Hassoon, D. Dziki, A. Miś, and B. Biernacka, "Wheat grinding process with low moisture content: A new approach for wholemeal flour production," *Processes*, 9(1). 32, 2021. <https://doi.org/10.3390/pr9010032>.
- [6] P. O. Ibidapo, A. A. Osibanjo, W. B. Asiru, O. F. Kayode, O. E. Ojo, and G. N. Elemo, "Proximate composition and bread-making performance of selected wheat varieties grown in Nigeria," *Nigeria. Nigerian Food Journal*, 36(2) 45–55, 2019.
- [7] E. Jayeola and B. A. Olunlade, "Production of Bread from Composites of Wheat, Maize, and Soybeans Flours," *Journal of Nutrition and Food Processing*, 7(12), 2024. <https://doi.org/10.31579/2637-8914/260>.
- [8] T. J. Jesulagba, D. Andrea, Z. A. Abiodun, O. Ogheneovo, and A. Abdulsalam, "Cost Evaluation of Bread Production from Composite of Wheat Flour and Corn Flour," *Asian Journal of Food Research and Nutrition*, 3(1), 190-201, 2024.
- [9] V. S. Kumari, C. Sindhu, and J. Singh, "Nutritional evaluation of indigenously developed weaning food from malted sorghum incorporated with soybean and raw banana flour," *International Journal of Current Microbiology and Applied Sciences*, 6(6) 1264–1271, 2017.
- [10] I. C. Ohanenye et al., "Food fortification technologies: Influence on iron, zinc and vitamin A bioavailability and potential implications on micronutrient deficiency in sub-Saharan Africa," *Scientific African*, 11(e00667) 2021. <https://doi.org/10.1016/j.sciaf.2020.e00667>.
- [11] G. I. Oluwafemi and K. T. Araoye, "Quality evaluation of composite bread produced from wheat, cassava, plantain, corn and soy-bean flour blends," *American Journal of Food Science and Nutrition*, 4(4) 42–47, 2017.
- [12] T. A. Shitu, F. B. Fadeyi, and M. A. Ladipo, "Impact of cassava flour properties on the sensory quality of composite white bread," *Quality Assurance and Safety of Crops & Foods*, 2(3), 2015. <https://doi.org/10.3920/QAS2014.0451>.