

Chemical and Sensory Properties of Bread Produced Using Wheat (*Aestivum Triticum*), OAT (*Avena Sativa L.*), Pigeon Pea (*Cajanus Cajan*) And Unripe Plantain (*Musa Paradisiaca*) Flour Blends

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Abstract—Background: This study evaluated the physical, chemical, mineral, and sensory properties of bread produced from blends of wheat (*Triticum aestivum*), oat (*Avena sativa L.*), unripe plantain (*Musa paradisiaca*), and pigeon pea (*Cajanus cajan*) flours. **Methods:** Five formulations were developed: AAA (50% wheat + 50% oat), BBB (40% wheat + 40% oat + 10% plantain + 10% pigeon pea), CCC (35% wheat + 35% oat + 15% plantain + 15% pigeon pea), DDD (30% wheat + 30% oat + 20% plantain + 20% pigeon pea), and FFF (100% wheat). **Results:** Proximate analysis revealed that moisture content ranged from 23.77% to 30.16%, with higher inclusion of plantain and pigeon pea flour increasing water retention. Crude protein and carbohydrate contents showed inverse trends, decreasing and increasing respectively with wheat substitution. Crude fibre and ash contents were enhanced in composite breads containing plantain and pigeon pea. Mineral analysis indicated significant increases ($p < 0.05$) in iron, calcium, phosphorus, magnesium, and potassium in composite breads, highlighting their potential for micronutrient fortification. Sodium content remained low across all samples. Sensory evaluation showed that 100% wheat bread (FFF) and wheat-oat bread (AAA) had the highest acceptability scores, while moderate inclusion of plantain and pigeon pea ($\leq 15\%$) produced bread with acceptable sensory attributes. Higher substitution levels (20% each) led to denser loaves with reduced aroma, texture, and taste. **Conclusion:** Overall, the study demonstrates that wheat-oat-plantain-pigeon pea composite breads can enhance nutritional quality, particularly mineral and fibre content, while maintaining consumer acceptability at moderate substitution levels.

I. INTRODUCTION

High-fibre snacks are crucial for human well-being, with main sources including whole grains, legumes, nuts, fruits, and vegetables (Obasi and Ifediba, 2018). Adequate fibre intake reduces the risk of type-2 diabetes [47] and obesity [20]. Incorporating fibre into staple foods like bread is a cost-effective strategy to help consumers meet recommended daily intake (Li & Komarek, 2017). Bread, the second most consumed non-indigenous food in Nigeria after rice (Gambo & Abubakar, 2014), is produced mainly from flour, water, yeast, and salt through mixing, kneading, proofing, shaping, and baking [7]. It is a good source of macronutrients (carbohydrates, protein, fat) and micronutrients (vitamins and minerals) essential for health [41]. Bread production increasingly utilizes diverse flours, including wheat, cassava, maize, potatoes, breadfruit [8], and soybean. However, Nigeria produces only about 2% of its wheat consumption, relying heavily on imports (FAO, 2021), which threatens food security in the bakery sector.

Composite flours from legumes can improve nutrition and promote dietary diversity (Feyera, 2020; Banua et al., 2021; Alliance, 2015). Plantain (*Musa paradisiaca*), widely cultivated in southern Nigeria, is a starchy fruit rich in potassium, iron, and beta-carotene, and is suitable for weight management and diabetic diets (Adebayo et al., 2021; Okorie et al., 2022). Pigeon pea (*Cajanus cajan*), though underutilized in Nigeria, improves protein quality when combined with starchy staples (Adeola et al., 2012; Muoki et al., 2012; Emmanuel-Ikpeme et al., 2012). Oats (*Avena sativa*), the fifth largest cereal globally, are rich in dietary fibre, particularly β -glucan, and offer significant health benefits (Joyce et al., 2019; Huijia-Mao et al., 2021; Vilpola et al., 2021).

Global demand for nutritious bread is rising due to increased awareness of healthy eating [45]. Alternative flours such as oat, pigeon pea, and unripe plantain have potential for bread production, enhancing nutrient content and health benefits (Adelekan et al., 2020; Akubor et al., 2019; Olorunsola et al., 2020). However, limited research exists on the combined use of these flours in bread [25]. This study aims to investigate the effects of different flour blends on bread quality.

II. MATERIALS AND METHODS

Source of raw materials

All-purpose wheat flour, Pigeon pea (*Cajanus cajan*), Unripe plantain (*Musa paradisiaca*) fingers, margarine, salt, egg, baking powder, vanilla essence flavor and vegetable oil) was obtained from Anyigba Central Market, Dekina Local Government Area of Kogi State while Oat (*Avena sativa* L.) was obtained from Karu Market, Abuja FCT, Nigeria.

Sample preparation

Pigeon pea Flour Production

The pigeon pea flour was produced using the method described by Bello et al. (2019). The Pigeon pea was sorted and cleaned to remove dirt, stones, chaffs and damaged seeds. The cleaned seeds were washed with potable water and dehulled, roasted at 120°C for 20 minutes and milled. The

pigeon pea flour was sieved to produce fine flour and packaged in an air tight container and kept for analysis.

Production of Plantain Flour

The plantain flour was produced using the method of Nwakalor and Obi (2014). One kilogram (1kg) of plantain in its mature stage was de-handed, peeled, sliced thinly, and steeped in water immediately to avoid browning. These slices were dried in a hot air oven at 60o C for 2 hours. The dried slices were milled and screened through a mesh into fine flour and packaged as plantain flour.

Preparation of oat flour

The method described by Girardet and Webster (2011) was adopted for the production of Oat Flour with slight modification. The oat grains were carefully sorted and cleaned to remove bad grains and foreign particles present as a result of the harvesting and transportation process. The oat grains were then washed properly with clean water to remove dust or sand particles after which the water is drained. It then undergone steaming by applying live steam for 9 minutes and then applying heat at about 100 °C for 45 minutes, known as kilning. This is done to develop flavour and prevent rancidity. The kilned oats were then subjected to dry heat in a hot air oven (model Schutzartdinen 6052G-1p20) to evaporate excess moisture and produce desirable nutty flavours. It was cooled to reduce temperature and remove moisture to a final water content of 10%. The cooled oat was then milled into fine flour and packaged in an airtight container until used.

Table 1: Sample formulation

Samples	Wheat flour (%)	Oat flour (%)	Unripe plantain flour (%)	Pigeon pea flour (%)
AAA	50	50	0	0
BBB	40	40	10	10
CCC	35	35	15	15
DDD	30	30	20	20
FFF	100	0	0	0

Sample codes

AAA = 50% wheat + 50% oat flour; BBB = 40% wheat flour + 40% oat flour + 10% unripe plantain flour + 10% pigeon pea flour; CCC = 35% wheat flour + 35% oat flour + 15% unripe plantain flour + 15% pigeon pea flour; DDD = 30% wheat flour + 30% oat flour + 20% unripe plantain flour + 20% pigeon pea flour; FFF = 100% wheat flour

Bread Production

The straight dough method was used to produce the bread; this method involves the addition of all ingredients (unripe plantain flour, pigeon pea flour, oat flour, salt, water, yeast etc.) at mixing stage and kneading same to obtain the dough. The different dough samples were placed in baking pans smeared with vegetable oil and was covered for the dough to ferment resulting in gas production

and gluten development for about 1 hour. The dough was baked in the oven at 230°C for 30 minutes. The baked loaves were carefully removed from the pans and allowed to cool and packaged in polyethylene bags for analysis (Ukeyima, 2019).

Proximate composition

Moisture, ash, fat, crude fibre, crude protein and carbohydrates content were determined according to the standard methods of Association of Official Analytical Chemists (AOAC, 2012).

Determination of Mineral content

The mineral content (iron, calcium, phosphorus and magnesium) of samples was determined according to AOAC (2012) standard procedure and the results obtained after three readings and expressed in mg/100g.

Sensory evaluation

Thirty (30) semi-trained panelists were selected to carry out sensory evaluation (Acceptance Test) on the flavor, crust/crumb colour, taste, mouthfeel and overall acceptability of the produced bread samples. The panelists were chosen depending on their health status, interest, emotional state, age and motivation of the individual to carry out the sensory evaluation. The samples were presented to the panelists at room temperature and in a uniform manner. They were coded in such a way that judges could not distinguish them by their code. They were randomly presented to avoid bias. Samples for reference was scored using 9-point Hedonic in which 1 means extremely dislike and 9 means extremely like (Iwe et al., 2014).

Statistical analysis

The data generated were analyzed with SPSS version 17.0 for Windows (SPSS Inc, Chicago, IL) using One-Way ANOVA, whereas the means were separated using Duncan's multiple range test at $P = 0.05$.

III. RESULTS AND DISCUSSION

Table 2 shows the proximate composition of bread made from wheat, oat, unripe plantain, and pigeon pea flour blends. Moisture content ranged from 23.77% (AAA) to 30.16% (FFF), with significant differences ($p < 0.05$). Bread with equal wheat and oat flour (AAA) had the lowest moisture, while 100% wheat bread (FFF) had the highest. The increase in moisture with higher unripe plantain and pigeon pea inclusion suggests their greater water absorption capacity, consistent with [5]. However, higher moisture may accelerate microbial spoilage, potentially reducing shelf life [37].

Ash content, indicating mineral content, ranged from 1.03% (FFF) to 1.38% (DDD). Sample DDD (30% wheat, 30% oat, 20% plantain, 20% pigeon pea) had the highest ash content, showing that

moderate inclusion of plantain and pigeon pea enhances mineral enrichment, similar to findings by [9].

Crude fat varied from 0.61% (FFF) to 1.61% (DDD), increasing with plantain and pigeon pea inclusion. This is attributed to the higher lipid content of legumes (Olaleye et al., 2017). Moderate fat improves energy and palatability, but excessive fat may reduce storage stability due to oxidative rancidity (Okoye and Obi, 2021).

Crude protein decreased from 12.08% (AAA) to 6.00% (FFF). The high protein in AAA reflects the protein quality of wheat and oats [29], while substitution with plantain and pigeon pea lowered protein due to the lower protein density of plantain flour, despite pigeon pea being a legume. Reduced gluten from these substitutions may also affect bread structure [44].

Crude fibre ranged from 5.83% (FFF) to 18.49% (DDD), highest in DDD due to fibre-rich plantain and pigeon pea (Okoye and Obi, 2021). Fibre-enriched breads promote digestive health, reduce cholesterol, and help manage blood glucose, benefiting consumers with lifestyle-related diseases (Adeola and Ohizua, 2018).

Carbohydrate content varied from 42.71% (DDD) to 56.37% (FFF), highest in FFF due to the starchy nature of wheat. Increased legume inclusion lowered carbohydrate content, reflecting the higher protein and fibre contribution of legumes [12]. High-carbohydrate bread provides quick energy, while lower-carbohydrate formulations may suit individuals monitoring carbohydrate intake.

Table 2: Proximate composition of bread produced from wheat, oat, unripe plantain and pigeon pea flour blends

Sample	Moisture (%)	Ash (%)	Crude Fat (%)	Crude Protein (%)	Crude Fibre (%)	Carbohydrates (%)
AAA	23.77 ^e ±0.04	1.10 ^c ±0.00	0.66 ^d ±0.03	12.08 ^a ±0.11	15.40 ^d ±0.06	46.99 ^c ±0.04
BBB	24.20 ^d ±0.14	1.18 ^b ±0.04	0.79 ^d ±0.01	9.30 ^b ±0.14	16.76 ^c ±0.00	47.78 ^b ±0.30
CCC	26.50 ^c ±0.03	1.20 ^b ±0.00	0.96 ^c ±0.03	8.57 ^c ±0.04	17.90 ^b ±0.06	44.87 ^d ±0.05
DDD	27.69 ^b ±0.16	1.38 ^a ±0.04	1.61 ^a ±0.03	8.12 ^d ±0.03	18.49 ^a ±0.09	42.71 ^e ±0.08
FFF	30.16 ^a ±0.03	1.03 ^d ±0.04	0.61 ^e ±0.01	6.00 ^e ±0.00	5.83 ^e ±0.06	56.37 ^a ±0.07

Values are mean ± standard deviation (n = 2). Means with different superscript along same column are significantly different (P<0.05). AAA = 50% wheat + 50% oat flour; BBB = 40% wheat flour + 40% oat flour + 10% unripe plantain flour + 10% pigeon pea flour; CCC = 35% wheat flour + 35% oat flour + 15% unripe plantain flour + 15% pigeon pea flour; DDD = 30% wheat flour + 30% oat flour + 20% unripe plantain flour + 20% pigeon pea flour; FFF = 100% wheat flour.

Mineral Composition of Bread Produced from Wheat, Oat, Unripe Plantain, and Pigeon Pea Flour Blends

The mineral composition of bread samples varied significantly ($p < 0.05$) across blends, showing that inclusion of unripe plantain and pigeon pea substantially improved micronutrient content. Iron (Fe) ranged from 3.50 mg/100 g in AAA (50% wheat + 50% oat) to 5.60 mg/100 g in DDD (30% wheat + 30% oat + 20% plantain + 20% pigeon pea). The increase in Fe with higher substitution

reflects the iron-rich nature of legumes like pigeon pea [10] and aligns with previous reports on wheat–legume composite breads (Olapade and Oluwamukomi, 2020), highlighting the potential of these formulations to address iron deficiency.

Calcium (Ca) increased from 32.51 mg/100 g in AAA to 50.00 mg/100 g in DDD, indicating that partial replacement of wheat with plantain and pigeon pea enhances Ca content. Plantain and legumes are known sources of bioavailable calcium [33], supporting findings by [21] that such composite breads can benefit populations at risk of calcium deficiency.

Phosphorus (P) ranged from 300.04 mg/100 g (AAA) to 420.01 mg/100 g (DDD), with higher levels observed in blends containing more plantain and pigeon pea. Phosphorus is essential for energy metabolism and bone health, and these values are comparable to bread fortified with legumes and tubers (310–450 mg/100 g) (Akinola and Idowu, 2019), indicating the complementary nutritional effect of non-wheat flours.

Magnesium (Mg) increased steadily from 110.06 mg/100 g (AAA) to 170.20 mg/100 g (DDD), reflecting the high Mg content of pigeon pea (Olapade and Adeyemo, 2014). Magnesium supports enzymatic reactions, neuromuscular function, and carbohydrate metabolism, and similar enhancements in legume-enriched baked products have been reported (Akubor and Ukwuru, 2019).

Sodium (Na) remained relatively low (6.68–9.10 mg/100 g), as it primarily originates from added salt rather than flour. Low Na is advantageous for cardiovascular health, contrasting with conventional breads that often contain higher sodium levels [30].

Potassium (K) increased from 280.20 mg/100 g (AAA) to 490.05 mg/100 g (DDD), reflecting the potassium richness of unripe plantain [21]. High K content improves electrolyte balance, nerve function, and muscle contraction, and the favorable K/Na ratio suggests that these composite breads may help reduce hypertension risk [2].

Table 3: Mineral composition (mg/100g) of bread produced from wheat, oat, unripe plantain and pigeon pea flour blends

Sample	Iron (Fe)	Calcium (Ca)	Phosphorus (P)	Magnesium (Mg)	Sodium (Na)	Potassium (K)
AAA	3.50 ^c ±0.05	32.51 ^c ±0.50	300.04 ^c ±3.10	110.06 ^c ±1.06	6.68 ^d ±0.10	280.20 ^c ±0.60
BBB	4.20 ^d ±0.06	38.20 ^d ±0.60	340.20 ^d ±2.00	130.04 ^d ±1.06	7.20 ^e ±0.10	350.01 ^d ±1.80
CCC	4.90 ^e ±0.05	44.03 ^e ±0.50	380.36 ^e ±1.80	150.01 ^e ±1.08	8.60 ^b ±0.10	420.20 ^e ±1.10
DDD	5.60 ^a ±0.06	50.00 ^a ±0.60	420.01 ^a ±1.08	170.20 ^a ±2.01	9.10 ^a ±0.10	490.05 ^a ±0.12
FFF	5.10 ^b ±0.05	46.00 ^b ±0.50	401.20 ^b ±1.19	160.06 ^b ±2.09	8.50 ^b ±0.10	460.10 ^b ±0.10

Values are mean ± standard deviation (n = 2). Means with different superscript along same column are significantly different (P<0.05). AAA = 50% wheat + 50% oat flour; BBB = 40% wheat flour + 40% oat flour + 10% unripe plantain flour + 10% pigeon pea flour; CCC = 35% wheat flour + 35% oat flour + 15% unripe plantain flour + 15% pigeon pea flour; DDD = 30% wheat flour + 30% oat flour + 20% unripe plantain flour + 20% pigeon pea flour; FFF = 100% wheat flour.

The sensory evaluation of bread samples showed significant differences ($p < 0.05$) in appearance, aroma, texture, taste, and overall acceptability (Table 4.5). Bread made from 100% wheat flour (FFF) and 50% wheat + 50% oat flour (AAA) received the highest scores, reflecting panelists' preference for crust color, flavor, and crumb texture. This is attributed to wheat's gluten-forming proteins, which enhance dough elasticity and loaf volume, while oat flour contributes beta-glucans and lipids that improve aroma and moisture retention (Olaoye et al., 2020; Flander et al., 2007). The overall acceptability scores were highest for AAA (8.15) and FFF (8.30).

Partial incorporation of unripe plantain and pigeon pea flour (10% each in BBB) maintained acceptable sensory ratings, with taste (7.90) and overall acceptability (7.75) comparable to control. Plantain provides resistant starch and fiber, while pigeon pea enriches protein quality (Onwurafor et al., 2021; Ayinde et al., 2023). At moderate substitution (15% each, CCC), slight declines in texture (7.10) and aroma (7.40) were observed, likely due to gluten dilution reducing gas retention and loaf softness (Okpala & Okoli, 2015).

High substitution (DDD) led to marked declines in acceptability. Bread was perceived as denser, less elastic, and slightly bitter, due to residual anti-nutritional factors in pigeon pea (Adebowale et al., 2011) and earthy flavors from plantain flour. Higher fiber and moisture content (Table 4.1) also contributed to denser crumbs. Similar trends have been reported in legume- and plantain-enriched breads at substitution levels above 20% (Olapade and Adeyemo, 2014; Akubor and Ukwuru, 2019).

Aroma scores followed a similar pattern, highest in AAA (8.10) and FFF (8.08), declining with increased plantain and pigeon pea inclusion. Reduced gluten limited Maillard reaction products, weakening desirable aroma, while pigeon pea can introduce beany or nutty flavors (Chinma et al., 2012; Alamu et al., 2020).

Overall, substitution up to 10–15% achieves nutritional enhancement while maintaining acceptable sensory quality, balancing functionality and health benefits. Wheat-oat bread remains most preferred, but moderate plantain and pigeon pea inclusion offers improved dietary protein and micronutrient intake without compromising consumer acceptability [42], particularly relevant in regions like Nigeria with high bread consumption and prevalent micronutrient deficiencies.

Table 4: Sensory properties of bread produced from wheat, oat, unripe plantain and pigeon pea flour blends

Sample	Appearance	Aroma	Texture	Taste	Overall Acceptability
AAA	8.20 ^a ±0.20	8.10 ^a ±0.25	7.85 ^a ±0.33	8.30 ^a ±0.28	8.15 ^a ±0.22
BBB	7.80 ^{ab} ±0.25	7.75 ^{ab} ±0.30	7.60 ^{ab} ±0.40	7.90 ^{ab} ±0.32	7.75 ^{ab} ±0.27
CCC	7.50 ^b ±0.28	7.40 ^b ±0.26	7.10 ^b ±0.35	7.30 ^b ±0.31	7.20 ^b ±0.29
DDD	7.00 ^c ±0.33	7.10 ^c ±0.29	6.70 ^c ±0.37	6.85 ^c ±0.34	6.90 ^c ±0.30
FFF	8.10 ^a ±0.30	8.10 ^a ±0.28	8.10 ^a ±0.42	8.20 ^a ±0.36	8.30 ^a ±0.34

Values are mean ± standard deviation (n = 30). Means with different superscript along same column are significantly different ($P < 0.05$). AAA = 50% wheat + 50% oat flour; BBB = 40% wheat flour + 40% oat flour + 10% unripe plantain flour + 10% pigeon pea flour; CCC = 35% wheat flour + 35% oat flour + 15% unripe plantain flour + 15% pigeon pea flour; DDD = 30%

wheat flour + 30% oat flour + 20% unripe plantain flour + 20% pigeon pea flour; FFF = 100% wheat flour

IV. CONCLUSION

The study demonstrated that incorporating oat, unripe plantain, and pigeon pea flours into wheat bread enhanced its nutritional and mineral content, notably increasing fibre, ash, and essential minerals, while sodium remained low. Moderate substitution (10–15%) maintained acceptable sensory qualities, whereas higher levels (20%) negatively affected texture and taste due to reduced gluten and higher fibre. Overall, these composite breads offer a practical approach to improving dietary protein and micronutrient intake without compromising consumer acceptability.

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