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Evaluation of Chemical and Sensory Properties of Bread Made from Wheat (*Triticum aestivum*) and African Yam Bean (*Sphenostylis stenocarpa)* Flour Blends

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Abstracts

This study evaluated chemical and sensory properties of bread made from wheat (*Triticum aestivum*) and African yam bean (*sphenostylis stenocarpa)* flour blends. The study determined the proximate, functional, micronutrient, and sensory attributes of bread made from blends of wheat and African yam bean flour. Wheat and African yam beans were processed into flour and were divided into six portions. The first two portions were the control (100% wheat and African yam bean flour) while the remaining portions of wheat flour were enriched with African yam bean flour at different ratios of 10, 20, 30, and 40 percent respectively. Data was analyzed using one-way analysis of variance (ANOVA) and separated by Ducan new multiply range test (DMRT). Significance was acceptable at ($p \le 0.05$). Results obtained showed that the proximate and mineral composition of the bread increased with an increased level of African yam bean flour. Substitution ratio of 60:40 had the highest content of protein (13.92 %), crude fat (13.49 %), crude fiber (1.05 %), crude ash (1.89 %), moisture content (28.00 %), potassium (12.78 mg/100g), Iron (1.83 mg/100g), magnesium (36.96 mg/100g), and Calcium (25.40 mg/100g) contents respectively compared to the bread made from 100 % wheat flour. Water absorption and bulk density ranged from 0.62 -145.03, and 0.27 – 0.37 g/ml respectively. From the sensory results, wheat flour bread (control sample) had the highest overall acceptability. However, products with 10 and 20 percent African yam bean substitution were most accepted by the panelists compared to other blended samples.

Keywords: Bread, African yam bean, Wheat, Proximate, Analysis, Sensory, Properties.

Introduction

Bread is a staple food consumed extensively in Nigeria, with the baking industry representing a significant sector of the national economy. However, Nigeria's heavy reliance on wheat imports places enormous strain on foreign exchange reserves, with the country spending billions of naira annually to import wheat for domestic bread production (Popoola *et al.,* 2023). This import dependency creates economic vulnerability and threatens food security, particularly given fluctuating global wheat prices and currency instability. Consequently, food researchers and policymakers have intensified efforts to develop composite flour technologies that substitute wheat with locally available, underutilized crops (Popoola *et al.,* 2023). The incorporation of indigenous legumes such as African yam bean (Sphenostylis stenocarpa) into bread formulations represents a viable strategy to reduce wheat imports, lower production costs, enhance the nutritional profile of bread, and promote the utilization of neglected but highly nutritious local crops (Knez *et al.,* 2023).

Functional components in bakery products are increasing, and many developing nations import wheat due to high consumption. Reducing wheat imports and using locally available raw materials like legumes and African yam beans could benefit the economy (Popoola *et al.,* 2023). Composite flour is being studied. Bread fortified with edible plant derivatives like roots and legumes enhances human health by improving the biological and nutritional value of foods and also to combat unbalanced nutrition, particularly protein, and energy malnutrition (Popoola *et al.,* 2023). Wheat, a high-volume, soft flour, is used for bread production due to its gliadin and glutenin content. However, it's expensive and not always available, so composite flour is used. Legumes are essential for diet and well-being. Legumes are essential constituents of diet and play important roles in sustaining the well-being of people owing to the high nutritional contents and functional properties of their seeds (Popoola *et al.,* 2023). Although the major grain legumes have received a lot of attention over the years, neglected legumes are also becoming increasingly recognized as potential crops to reduce hunger and increase food security in Africa. These neglected legumes can be used as functional foods since they are high in vitamins, proteins, and dietary fiber among other nutrients. Among them is the African yam bean (AYB) (Sphenostylis stenocarpa), which is grown for its tubers in East and Central Africa and its seeds in West Africa (Adewale and Nnamani, 2022).

African yam bean (Sphenostylis stenocarpa) is an underutilized crop with significant nutritional potential. African yam bean (AYB) has been utilized to create fortified and enriched foods due to its high protein content and other nutritional benefits (Babarinde *et al.,* 2019). The varieties of African yam beans vary, ranging from creamy white to speckled black, with brown tones in between. It is widely farmed in Nigeria's northern region (Adewale and Nnamani, 2022). African yam beans have harmful components in them that could harm or hinder the availability of minerals and the digestion of proteins. Nevertheless, when African yam beans are heated to make bread, these hazardous compounds become inactive due to heat lability. It is eaten in various ways and has a greater capacity to absorb water than cowpeas. African yam bean can be processed into flour, which increases their versatility, particularly in the confectionery industry (Oomojokun and Oyedele, 2021). The use of African yam bean flour in bread production could improve the quality, nutritional, and health benefits of the bread while reducing wheat import costs, and lowering bread unit prices. Thus, this work aims to substitute a portion of the wheat in bread production with African yam bean flour to improve the bread's nutritious content, increase the use of African Yam bean seeds, and minimize or stop their extinction which is the reason for this research.

Objectives of the study

This study evaluated nutrient composition and sensory properties of bread produced from blends of wheat and African yam bean flour. Specifically, the study determined:

1. proximate and micronutrient composition of the bread samples.
2. functional properties of the flour blends
3. sensory attributes and acceptability of bread made from a composite flour blend of wheat and African yam bean

Materials and Methods

***Design of the Study*:** The study adopted pure experimental research. African yam bean seeds and wheat were purchased and processed into flour. The flours were combined in proportional ratios for analysis.

***Procurement of Raw Materials*:** The ingredients, including wheat grains, white African yam bean, yeast, sugar, baking powder, margarine, powdered milk, and egg, were procured from Ogige Market in Nsukka Local Government, Enugu State, Nigeria.

***Preparation of Materials*:** African yam bean and wheat were separately processed into flour as follows:

African Yam Bean Flour: One kilogram of white African yam bean seeds was sorted to remove foreign materials, boiled for 10 minutes, and soaked in cold water for 24 hours to loosen seed coatings and reduce antinutrient levels. The seeds were dehulled, steeped for three hours, rasped, and sun-dried for 12 hours. The dried seeds were milled and sieved using a 0.4 mm sieve.

Wheat Flour: Wheat grains were sorted, washed, and soaked for 45 minutes. The soaked grains were sun-dried for 12 hours, milled, and finely sieved using a 0.4 mm sieve.

Formulation of Composite Flour Ratio and Codes: Composite Blends of African yam bean and wheat flours were combined in six proportional ratios:

WFF: Wheat flour only 100%

AYBF: African yam bean flour only.

WAYBF1: Wheat flour and African yam bean flour (90:10).

WAYBF2: Wheat flour and African yam bean flour : (80:20).

WAYBF3: Wheat flour and African yam bean flour (70:30).

WAYBF4: Wheat flour and African yam bean flour (60:40).

Production of Bread: A modified straight dough method was adopted (AOAC, 2010).

Recipe for Production of Bread:

Ingredients	**Measurement**
Flour	1000g
Margarine	14g
Yeast	8g
Sugar	14g
Water	300mls
Salt	10g

Procedure for Production of Bread

- Dry ingredients (flour, salt, milk powder) were mix thoroughly.
- Yeast was dissolved in warm water with sugar and allowed to activate (yest solution).
- Yeast solution was combined with dry ingredients and mixed to form dough.

- Dough was proofed for 50 minutes at ambient temperature, then kneaded and treated with margarine to improve texture and smoothness.
- Dough was panned and baked at 180^{o}C for 50 minutes. Breads were cooled to room temperature prior to analysis.

***Proximate Analysis*:** Bread samples were analyzed in triplicate using standard methods as described by the AOAC, (2010) method, for the following:

Moisture: Moisture was determined using thermogravimetric in a muffle furnace (Sanyo Gallenkamp, Weiss Technik West Midlands, UK) at 500C for 24 hours. Crude Fat was determined by exhaustive extraction of a 0.5 g sample with petroleum ether in a micro Soxhlet extraction unit (Gerhardt, Bonn, Germany).

Protein: Protein *determination* was done by the Kjeldal method After distillation and titration, nitrogen was corrected using a factor of 6.25.

Crude fiber: Crude fiber was determined by the loss in weight of the bread sample after ignition divided by the original weight of the sample multiplied by a hundred.

Ash: Ash was determined by drying the sample at 100C for 3-4 hours in a mechanized convection air oven (VRW 1370, Sheldon Manufacturing Corporation, Oregon, USA) and transferred to the muffle furnace to be charred. Ash was obtained by the difference in weight.

Carbohydrate: This determined by the difference of moisture, protein, fat, fiber, and ash from 100 percent.

***Mineral Analysis*:** The mineral content of bread was assessed using AOAC (2010), determining calcium, potassium, magnesium, and iron using an atomic absorption spectrophotometer. The samples were ignited, dissolved with hydrochloric acid, and analyzed for absorbance. Iron absorbance was measured at 510nm.

Functional Properties: Determination of water Absorption Capacity and bulk density

The weight of water absorbed was determined by centrifuging samples with distilled water at 3500 RMP for 20 minutes, and bulk density was calculated by adding a 20-gram sample to a 50-milliliter measuring cylinder as described by Udoro &Kehinde (2014).

Sensory Evaluation: The panel consisted of a 20-man semi-trained panelist comprising of students and staff members from the Department of Food Science and Technology, University of Nigeria, Nsukka. These panelists were selected for their ability to provide informed opinions on food products based on prior training and familiarity with basic sensory evaluation techniques. A nine-point hedonic scale coded as extremely, 9; like very much, 8; like moderately, 7; like; slightly, 6; neither like or dislike, 5; dislike slightly, 4; dislike moderately, 3; dislike very much, 2; dislike extremely was used. Sensory attributes evaluated by included colour, taste, appearance, mouthfeel, texture, crumbiness, aroma, after taste, and overall acceptability, bread samples coded WAYBF1-WAYBF4 were presented in random order to minimize bias. Drinking water was provided between sample evaluations to cleanse the palate.

Data Analysis Technique: The data obtained was expressed as mean ± standard deviation. Results of two replicates were used. Analysis of variance

(ANOVA) was used to determine statistically significant differences between the means. Level of significance was at 5% level of probability ($p < 0.05$).

Findings of the Study

Table 1: Proximate Composition (%) of Wheat-African yam bean Bread

Samples	Moisture	Protein	Crude Fat	Fiber	Ash	CHO
WF	$5.74^{f}\pm0.48$	$16.45^{b}\pm0.00$	$2.74^{c}\pm0.08$	$0.65^{f}\pm0.00$	$1.54^{h}\pm0.00$	$72.88^{a} \pm 0.56$
AYBF	$6.92^{e}\pm0.59$	$21.85^{a}\pm0.00$	$3.04^{c}\pm0.78$	$10.46^{a}\pm0.00$	$2.19^{a}\pm0.00$	$55.54^{c} \pm 0.18$
WFB	$15.43^{d}\pm0.18$	$11.73^{e} \pm0.00$	$14.43^{ab} \pm2.79$	$0.85^{de} \pm0.00$	$1.58^{f} \pm0.00$	$55.98^{bc}\pm2.60$
AYBF	$16.66^{c}\pm0.79$	$14.34^{c}\pm0.62$	$15.16^{ab}\pm2.96$	$1.95^{b}\pm0.00$	$2.09^{b}\pm0.00$	$50.27^{f} \pm 4.37$
$WAYBF_1$	$16.78^{cd}\pm0.23$	$11.99^{e}\pm0.24$	$11.84^{a}\pm0.52$	$0.91^{cd}\pm0.00$	$1.62^{g}\pm0.02$	$56.86^{b}\pm 0.53$
$WAYBF_2$	$16.84^{bc}\pm0.44$	$13.03^{d}\pm0.00$	$12.57^{ab}\pm2.74$	$0.93^{cd}\pm0.18$	$1.70^{d}\pm0.00$	$54.93^{c} \pm 3.17$
$WAYBF_3$	$16.87^{b}\pm0.16$	$13.16^{d}\pm0.13$	$12.98^{ab}\pm1.11$	$1.05^{c}\pm0.00$	$1.74^{d}\pm0.00$	$54.20^{cd} \pm 1.07$
$WAYBF_4$	$17.04^{a}\pm0.66$	$13.92^{c}\pm0.12$	$13.49^{b}\pm0.01$	$1.05^{c}\pm0.00$	$1.89^{c}\pm0.01$	$52.61^{d} \pm 0.55$

Values are mean $\pm S.D$ of duplicate determinations. Values in the same column with different superscripts were significantly ($p< 0.05$) different.
WF: Wheat flour, AYBF: African yam bean flour, WFB: Bread from Wheat flour (100%), AYBF: Bread from African yam bean flour (100%), $WAYBF_1$: 90% Wheat flour and 10% African yam bean flour, $WAYBF_2$: 80% Wheat flour and 20% African yam bean, $WAYBF_3$: 70% Wheat flour and 30% African yam bean flour, $WAYBF_4$: 60% Wheat flour and 40% African yam bean flour.

Table 2 displays the results of the proximate composition of the bread samples from wheat–African yam beans, revealing significant ($p \leq 0.05$) differences. The moisture, protein, crude fat, crude fiber, crude ash, and carbohydrate content ranged from 15.43 - 17.04, 11.73 - 14.34, 11.84 -14.43, 0.85 - 1.05, 1.62 - 2.09, and 50.27 - 56.86 % respectively. African yam bean bread had the highest proximate composition compared with 100% wheat bread.

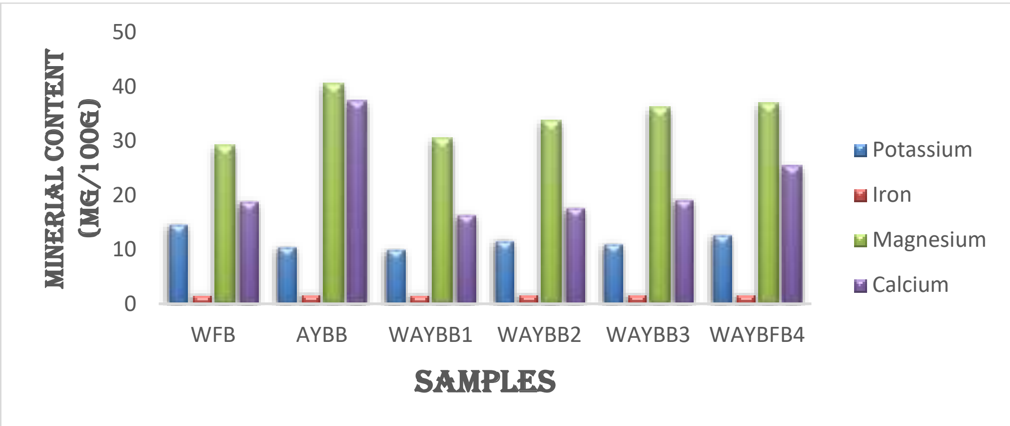

Figure 1: **Micronutrient Composition of the Bread Sample**
Keywords: WFB: wheat bread (100 %), AYBB: African yam bean bread (100%), $WAYBB_1$: wheat flour (90 %) and African yam bean (10 %), $WAYBB_2$: wheat flour (80 %) and African yam bean flour (20%), $WAYBB_3$: wheat flour (70 %) and African yam bean flour (30%), $WAYBB_4$: wheat flour (60 %) and African yam bean flour (40 %)

Figure 1 displays the results of the formulated bread's mineral analysis. The ranges for the potassium, iron, magnesium, and calcium contents were 10.14 to 14.73 mg/100 g, 1.70 to 1.83 mg/100 g, and 33.73 to 40.54 mg/100 g, respectively. Bread produced from 100 % African yam bean flour had a higher iron, magnesium, and calcium content but lower potassium content compared to 100 % wheat bread.

Table 3: Functional properties of flour blends

Samples	% Water absorption capacity	Bulk Density(g/mL)
WF	62.00^{e}±0.01	0.37^{a}±0.01
AYBF	84.01^{d}±0.01	0.30^{c}±0.01
$WAYBF_1$	93.02^{cd}±0.01	0.30^{c}±0.00
$WAYBF_2$	98.01^{c}±0,02	0.34^{b}±0.01
$WAYBF_3$	128.02^{b}±0.01	0.32^{bc}±0.04
$WAYBF_4$	145.03^{a}±0.03	0.27^{d}±0.03

Values are presented in mean ± standard deviation. Sample means with the different superscripts on the same column are significantly (p<0.05) different. Keywords: WFF: wheat flour (100%), AYBF: African yam bean flour (100%), $WAYBF_1$: wheat flour (90%) and African yam bean (10%) $WAYBF_2$: wheat flour (80%) and African yam bean flour (20%), $WAYBF_3$: wheat flour (70%) and African yam bean flour (30%) $WAYBF_4$: wheat flour (60%) and African yam bean flour (40%).

Table 3 shows flour blends' functional characteristics. The percentage of water that the flour samples could absorb varied from 62.0 to 145.03 percent. $WAYBF_4$ had the greatest value of 145.03%, while sample WF (100% wheat) had the lowest value of 62.0%. The level of water absorption in the flour blends increased significantly ($p < 0.05$) as the substitution of African yam beans increased. The effects of changes in bulk density ranged from 0.27 to 0.37 g/mL.

Table 4: Sensory Results of Bread from Wheat-African Yam Bean Flour Blends

Sample Parameters	WFB	AYBB	$WAYBB_1$	$WAYBB_2$	$WAYBB_3$	$WAYBB_4$
Colour	7.85^{a}±1.42	6.05^{b}±1.39	7.00^{ab}±1.17	6.75b±1.52	7.05^{ab}±1.61	6.20^{b}±1.64
Taste	7.60^{a}±1.47	4.05^{b} ±1.39	7.05^{ab}± 1.15	6.60ab±1.57	5.95^{a} ±2.04	5.80^{c}± 2.12
Appearance	7.50^{a}± 1.28	5.35^{b}± 1.39	7.05^{a} 1.09	6.95^{a} ±1.19	6.75^{a} ±1.25	5.70^{b} ±1.26
Mouthfeel	7.50^{b}± 1.28	4.70^{c} ±1.59	7.15^{a} 1.09	7.00^{a}± 1.08	5.75^{a}± 1.89	5.00^{bc}± 1.57
Texture	7.60^{a}± 1.31	5.00^{d} ±1.45	6.70^{ab} ±1.45	6.50^{bc} ±1.32	6.20^{bc} ±1.77	5.60^{cd} ±1.57
Crumbiness	7.10^{a}± 1.48	4.95^{c}± 1.73	6.75^{ab}± 1.59	6.75^{ab} ±1.45	6.25^{ab}± 1.59	5.80^{bc} ±1.28
Aroma	7.45^{a}± 1.39	4.75^{c}± 1.71	7.10^{a} ±1.07	6.95^{a}± 1.50	6.55^{ab}± 1.10	5.28^{b}± 1.59
After taste	7.30^{ab}± 1.81	5.20^{b}± 1.91	7.15^{a} ±1.23	6.74^{a} ±1.85	6.15^{a}± 1.57	5.25^{b}± 2.02
Overall acceptability	7.90^{a}± 1.37	4.75^{d} ±1.86	7.45^{ab}± 1.10	6.89^{bc}± 2.09	6.40^{bc}± 1.96	5.55^{cd}± 2.09

Values are presented in mean ± standard deviation. Sample means with the different superscripts on the same column are significantly (p < 0.05) different. Keywords: WFB: wheat bread (100 %), AYBB: African yam bean bread (100%), $WAYBB_1$: wheat flour (90 %) and African yam bean (10 %) $WAYBB_2$: wheat flour (80%) and African yam bean flour (20 %), $WAYBB_3$: wheat flour (70 %) and African yam bean flour (30%) $WAYBB_4$: wheat flour (60 %) and African yam bean flour (40%

Table 4 shows sensory profile results for formulated bread loaves, with colour ranging from 6.05 to 7.85, taste range from 4.05 to 7.60, and appearance ranging from 5.35 to 7.50.

Discussion of findings

The range of moisture content obtained in this study was higher when compared with the value of 5.59 – 8.21 reported by Alugwu *et al.* (2023). The study reveals that the moisture content of wheat-African yam bean flour blends had an impact on the shelf life of the bread loaves. Anhwange and Atoo (2015) found that moisture content significantly impacts the organoleptic, physical, and microbial properties of composite flour, increasing loaf volume and causing off-flavor in flours above 14 percent. There were variations in the protein content of the formulated bread loaves values, with the wheat flour bread (WFB) having the lowest (11.73 %) and African–yam bean bread AYBB having the highest (14.34 %) contents. The protein results in the study were similar to the 14.89 percent reported by Alugwu *et al.* (2023). The prepared bread samples had fat contents ranging from 11.84 to 14.43 %. The samples showed a substantial increase in fat content ($p < 0.05$). The study found that the fat content of bread samples significantly increased when African yam bean flour was used in flour blends due to lipolytic enzymes. Popoola *et al.* (2023) suggest that the high oil content in African yam beans may have contributed to an increase in fat content. The study reveals a significant increase in ash content with increasing African yam bean flour content, with sample WAYBB4 having the highest at 2.09 %. Shodehinde *et al.* (2022) discovered that African yam bean is abundant in ash, indicating its widespread availability of essential mineral elements in food samples. The result obtained is similar to 1.0 - 2.02 percent reported by Alugwu *et al.* (2023). The study found that African yam bean flour significantly increased fiber content in bread samples, possibly due to legume seed coatings, making it a potential functional food source and reducing lifestyle disease incidence (George *et al.,* 2020). The result of the crude fiber result obtained in this work was less than 3.41 – 5.62 reported by Egbujie *et al.* (2021). The carbohydrate content of the formulated bread samples ranged from 50.27 to 56.86%, with African-yam bean bread (AYBB) having the lowest at 50.27 % and WAYBB1 having the highest at 56.86 %. High carbohydrate content in flour blends boosts energy, while African yam bean's low carbohydrate, low-calorie, high fiber, and protein content can combat malnutrition-related health issues (Gropper *et al.,* 2018).

The mineral composition of the prepared bread samples is displayed in Figure 1. Significant levels of potassium, iron, calcium, and magnesium were found in the formulated bread samples. This is in contrast with potassium levels of 23.72 – 27.95mg/100g reported by Ibidapo *et al.* (2020) for bread made from a combination of wheat malted millet and Okara flour blends. It suggests that the potassium content of African yam beans is low. This also stands in contrast to the findings of Egbujie *et al.* (2021), that an increase in African yam bean flour proportionately enhanced the bread's potassium level. The addition of African yam bean flour to bread samples resulted in an increase in iron content, ranging from 1.70 to 1.89 mg/100g (Olatunde and Akinbisoye, 2024). Wheat flour, compared to African yam bean flour, lacks significant iron content, as indicated by the lowest iron concentration in 100% wheat flour, a crucial component of myoglobin (Gropper *et al.,* 2018). The calcium content of the formulated bread samples increased with an increased level of African yam bean flour added. African yam bean is rich in calcium as reported by Shodehinde *et al.* (2022). The result obtained was lower than

44.28mg/100g reported by Olatunde and Akinbisoye (2024). However, the present investigation observed calcium levels similar to the range of 19.13 to 25.24 ppm reported by Oyinloye *et al.* (2023) for bread derived from wheat, moringa, and coriander flour blends. The addition of African yam bean flour to the formulated bread samples increased its magnesium content, which is crucial for maintaining a strong immune system, heartbeat, nerve and muscle function, and bone strength (Gropper *et al.,* 2018). The results of the current study align with the findings given by George *et al.* (2020), which indicated that the African yam bean possesses high levels of magnesium and calcium.

The functional properties of the flour blends shows that the water absorption capacities ranged from 62.0 to 145.03 %. At 62.00 %, sample WF had the lowest value, and at 145.03 %, sample WAYBB4 had the highest. The water absorption capacity of African yam bean flour blends was enhanced due to variations in the amount of undamaged and damaged starch in the flour sample (Amon and Akinbode, 2022; Alugwu *et al.,* 2023). The values found in blends of wheat and African yam bean flour were similar to the range 60-140% reported by Alugwu *et al.* (2023). The bulk density of the composite flours is determined by their initial moisture content and particle size. The study found that increasing the amount of African yam bean flour in composite flour results in a significant ($p < 0.05$) decrease in its bulk density. The result obtained in the study was similar to the values 0.73 – 0.87 reported by Henry-Unaeze and Amadi (2022).

The sensory evaluation of the prepared bread samples. From the result obtained, the range of values for overall acceptability was 3.75 to 7.90. Samples WFB and WAYBB4 were relatively favorable and moderately undesirable respectively. Samples WFB (7.90) and WAYBB1 (7.45) had similar overall acceptability scores, with no statistically significant differences ($p < 0.05$). The result of the overall acceptability obtained is similar to that reported by Henry-Unaeze and Amadi (2022). When African yam bean flour was added in higher percentages, bread became darker and less appetizing, suggesting that food products should only contain minimal amounts of this flour. Perhaps due to its beany taste, a higher replacement of African yam bean flour for wheat flour in the bread's formulation decreased its popularity (Popoola *et al.,* 2023)

Conclusion

The study successfully demonstrated that incorporating African yam bean flour into wheat bread formulations offers a strategy for enhancing nutritional quality while simultaneously addressing the economic burden of wheat import dependency in Nigeria. The findings revealed that African yam bean flour significantly improved the proximate composition of bread, particularly protein, fat, ash, and fiber contents, thereby contributing to better nutritional outcomes for consumers. However, a clear trade-off emerged between nutritional enhancement and sensory acceptability, as higher substitution levels beyond 20% resulted in unacceptable beany flavor and reduced overall consumer preference. The optimal balance was achieved at 10–20% substitution levels, where the composite bread maintained sensory characteristics comparable to 100% wheat bread while delivering meaningful nutritional benefits. These results highlights the potential of African yam bean as a valuable indigenous crop for food fortification. Wheat-African yam bean composite bread represents a viable, cost-effective, and nutritionally better alternative that aligns with national food security objectives and public health goals.

Recommendation

Based on the study findings, the following recommendations are proposed:

Promote African yam bean utilization in baked products as an excellent protein source to combat protein-energy malnutrition and reduce dependence on expensive wheat imports substitution levels to 10 – 20% African yam bean flour in wheat bread formulations is recommended to achieve optimal nutritional enhancement without compromising sensory acceptability and consumer preference.

Optimize processing techniques through improved roasting, fermentation, or other pre-treatment methods to effectively mitigate beany flavor and broaden consumer acceptance of higher substitution levels in future product development.

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