

Influence of Moringa Seed Flour Fortification on the Sensory Acceptability of Bread Produced from Wheat Flour

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Abstract

This study evaluated the influence of moringa (*Moringa oleifera*) seed flour fortification on the sensory acceptability of bread produced from wheat flour. Three bread formulations were prepared: 100% wheat flour (control), 95:5 wheat–moringa seed flour, and 90:10 wheat–moringa seed flour. Sensory evaluation was conducted by ten panelists using a nine-point Hedonic scale to assess appearance, taste, texture, aroma, and overall acceptability. The results showed that moringa seed flour incorporation affected the sensory characteristics of the bread samples. The control bread recorded the highest mean scores for appearance (8.00 ± 0.94) and texture (7.70 ± 0.68), while bread containing 10% moringa seed flour recorded the highest scores for taste (7.40 ± 1.35), aroma (7.40 ± 1.51), and overall acceptability (7.80 ± 1.40). Bread containing 5% moringa seed flour had the lowest scores for all evaluated attributes but remained acceptable to the panelists. Significant differences ($p < 0.05$) were observed among the samples for the sensory attributes evaluated. The findings indicate that partial substitution of wheat flour with moringa seed flour, particularly at 10% inclusion, can produce bread with acceptable sensory characteristics. Moringa seed flour may therefore be considered a potential ingredient for developing nutritionally enhanced composite bread.

Keywords: Moringa Seed Flour; Hedonic Scale; Composite Flour; Functional Bakery Product; Wheat Substitution.

Introduction

Bread is one of the most widely consumed bakery products worldwide because of its convenience, affordability, pleasant sensory qualities, and nutritional contribution to the human diet. Bread also serves as an effective carrier for functional ingredients because of its widespread consumption and consumer familiarity, making it suitable for nutritional fortification strategies (Oyinloye *et al.*, 2024). As a staple food consumed daily across different age groups and socioeconomic classes, bread serves as an important vehicle for the delivery of nutrients and functional ingredients. In Nigeria, bread is commonly

consumed in homes, schools, restaurants, and other food outlets, making it a suitable product for nutritional intervention through food fortification.

The growing demand for healthier food products has stimulated interest in the development of composite flours by partially replacing wheat flour with locally available plant materials (Akintola *et al.*, 2025a). Composite flour technology has been widely promoted because it enhances the nutritional quality of bakery products, reduces dependence on imported wheat, and encourages the utilization of indigenous agricultural resources (Akintola and Anifowose, 2025). Among the various plant materials investigated for food fortification, *Moringa oleifera* has gained considerable attention owing to its rich nutritional composition and functional properties. Recent studies have demonstrated that moringa supplementation can enhance the nutritional and functional properties of bakery products, although the sensory acceptability of the final product may depend on the form and level of moringa incorporated (Eke *et al.*, 2022; Ferreira *et al.*, 2023).

Moringa oleifera seeds are rich sources of protein, essential fatty acids, vitamins, minerals, and other bioactive compounds that can improve the nutritional value of food products (Aremu and Akintola, 2016). Although moringa leaves have been extensively used in food fortification, moringa seeds possess comparatively higher levels of protein, lipids, and minerals, making them an attractive ingredient for enriching wheat-based products such as bread. Incorporating moringa seed flour into bread therefore presents an opportunity to produce bakery products with improved nutritional value while promoting the utilization of locally available agricultural resources.

Problem Statement

Despite the nutritional benefits associated with moringa seed fortification, the success of fortified bread depends largely on consumer acceptance. Consumers often evaluate bread based on sensory characteristics such as appearance, taste, texture, aroma, and overall eating quality. Consumer purchasing decisions are strongly influenced by sensory quality, particularly appearance, aroma, taste, and texture, which remain the primary determinants of repeat purchase of fortified bakery products (Oyinloye *et al.*, 2024). Consequently, even when nutritional quality is improved, any adverse effect on sensory properties may reduce consumer preference and limit the commercial viability of the product.

Sensory acceptability is therefore an essential consideration in the development of fortified bakery products (Akintola *et al.*, 2025b). Sensory evaluation provides an objective means of determining how consumers perceive product quality and identifying acceptable substitution levels that maintain desirable eating characteristics. By assessing sensory attributes using trained or semi-trained panelists, researchers can establish whether fortification improves or diminishes the overall acceptability of the final product. The balance between nutritional enhancement and sensory quality is critical for the successful adoption of composite bread formulations. This perspective aligns with the sensory evaluation approach employed in the present study, which assessed appearance, taste, texture, aroma, and overall acceptability using a 9-point hedonic scale.

Previous studies have demonstrated that incorporating plant-derived ingredients into wheat bread may influence loaf characteristics, flavour, crumb texture, colour, and aroma, thereby affecting consumer preference (Oyinloye *et al.*, 2024). Determining the optimum level of moringa seed flour substitution is therefore necessary to ensure that nutritional improvements are achieved without compromising the sensory qualities expected by consumers.

Objectives

This study was undertaken to evaluate the influence of moringa seed flour fortification on the sensory acceptability of bread produced from wheat flour. Specifically, bread samples prepared from 100% wheat flour, 95:5 wheat–moringa seed flour, and 90:10 wheat–moringa seed flour blends were evaluated for consumer acceptance based on appearance, taste, texture, aroma, and overall acceptability. The findings provided useful information on the suitability of moringa seed flour as a fortifying ingredient in bread production and contributed to the development of nutritious bakery products that meet consumer expectations.

Literature Review

Bread and Nutritional Fortification

Bread is one of the most widely consumed bakery products worldwide because of its convenience, affordability, pleasant sensory qualities, and nutritional contribution to the human diet. Bread also serves as an effective carrier for functional ingredients because of its widespread consumption and consumer familiarity, making it suitable for nutritional fortification strategies (Oyinloye *et al.*, 2024). As a staple food consumed daily across different age groups and socioeconomic classes, bread serves as an important vehicle for the delivery of nutrients and functional ingredients. In Nigeria, bread is commonly consumed in homes, schools, restaurants, and other food outlets, making it a suitable product for nutritional intervention through food fortification.

Composite Flour Technology and Moringa Fortification

The growing demand for healthier food products has stimulated interest in the development of composite flours by partially replacing wheat flour with locally available plant materials (Akintola *et al.*, 2025a). Composite flour technology has been widely promoted because it enhances the nutritional quality of bakery products, reduces dependence on imported wheat, and encourages the utilization of indigenous agricultural resources (Akintola and Anifowose, 2025). Among the various plant materials investigated for food fortification, *Moringa oleifera* has gained considerable attention owing to its rich nutritional composition and functional properties. Recent studies have demonstrated that moringa supplementation can enhance the nutritional and functional properties of bakery products, including their phenolic content and antioxidant activity, although consumer acceptance may depend on the form and level of moringa incorporated (Ferreira *et al.*, 2023).

Moringa oleifera seeds are rich sources of protein, essential fatty acids, vitamins, minerals, and other bioactive compounds that can improve the nutritional value of food products (Aremu and Akintola, 2016). Although moringa leaves have been extensively used in food fortification, moringa seeds possess comparatively higher levels of protein, lipids, and minerals, making them an attractive ingredient for enriching wheat-based products such as bread. Incorporating moringa seed flour into bread therefore presents an opportunity to produce bakery products with improved nutritional value while promoting the utilization of locally available agricultural resources.

Consumer Acceptance and Sensory Acceptability

Despite the nutritional benefits associated with moringa seed fortification, the success of fortified bread depends largely on consumer acceptance. Consumers often evaluate bread based on sensory characteristics such as appearance, taste, texture, aroma, and overall eating quality. Consumer purchasing decisions are strongly influenced by sensory quality, particularly appearance, aroma, taste, and texture, which remain the primary determinants of repeat purchase of fortified bakery products (Oyinloye *et al.*, 2024). Consequently, even when nutritional quality is improved, any adverse effect on sensory properties may reduce consumer preference and limit the commercial viability of the product.

Sensory acceptability is therefore an essential consideration in the development of fortified bakery products (Akintola *et al.*, 2025b). Sensory evaluation provides an objective means of determining how consumers perceive product quality and identifying acceptable substitution levels that maintain desirable eating characteristics. By assessing sensory attributes using trained or semi-trained panelists, researchers can establish whether fortification improves or diminishes the overall acceptability of the final product. The balance between nutritional enhancement and sensory quality is critical for the successful adoption of composite bread formulations. This perspective aligns with the sensory evaluation approach employed in the present study, which assessed appearance, taste, texture, aroma, and overall acceptability using a 9-point hedonic scale.

Previous studies have demonstrated that incorporating plant-derived ingredients into wheat bread may influence loaf characteristics, flavour, crumb texture, colour, and aroma, thereby affecting consumer preference (Nouska *et al.*, 2023). Determining the acceptable level of moringa seed flour substitution is therefore necessary to ensure that nutritional improvements are achieved without compromising the sensory qualities expected by consumers.

Materials and Methods

Study Location

The study was conducted in the Department of Agricultural and Bio-Environmental Engineering, Oyo State College of Agriculture and Technology (OYSCATECH), Igboora, Nigeria. Bread production and sensory evaluation were carried out under controlled laboratory conditions.

Materials

Commercial wheat flour was obtained from a baking flour depot, while mature *Moringa oleifera* seeds were harvested from the OYSCATECH Teaching and Research Farm. Other baking ingredients, including granulated sugar, salt, margarine, yeast, eggs, and baking powder, were purchased from the local market in Igboora, Oyo State.

Preparation of Moringa Seed Flour

The moringa seeds were manually dehulled to obtain the kernels. The kernels were dried using the cabinet tray drying method to preserve their nutritional quality. The dried kernels were subsequently subjected to manual hot-press oil extraction. The resulting defatted grits were dried, milled into fine flour using a laboratory blender, and sieved to obtain a uniform particle size suitable for bread production.

Formulation and Bread Production

Composite flour blends were prepared by substituting wheat flour with moringa seed flour at two levels: 5% and 10%. Three bread formulations were produced: Sample A (Control): 100% Wheat Flour (2Kg); Sample B: 90% Wheat Flour + 10% Moringa Seed Flour; Sample C: 95% Wheat Flour + 5% Moringa Seed Flour.

The flour blends were sieved through a 500- μ m mesh and mixed thoroughly with the baking ingredients to produce homogeneous dough. The dough was kneaded manually for approximately 40 minutes until a smooth and elastic consistency was obtained. After kneading, the dough was transferred into greased baking pans and allowed to ferment for 35 minutes at ambient temperature. Proofing was carried out for an additional 45 minutes before baking in a preheated oven for 30 minutes. The baked loaves were removed from the oven, cooled on wire racks, packaged in polyethylene bags, and stored under laboratory conditions before sensory evaluation.

Sensory Evaluation

The sensory acceptability of the bread samples was evaluated by a semi-trained panel of ten staff members and graduate students of Oyo State College of Agriculture and Technology, Igboora, Nigeria. The panelists were familiar with bread products but were not recruited to represent the general consumer population. Each panelist evaluated all three bread formulations under similar environmental conditions. Bread samples were allowed to cool for 12 hours after baking, sliced into uniform pieces and served on white plates identified with randomly generated three-digit codes to minimise sample identification bias. The sensory attributes evaluated were appearance, taste, texture, aroma and overall acceptability. A nine-point Hedonic scale was used, where 1 represented "Dislike Extremely", 5 represented "Neither Like nor Dislike", and 9 represented "Like Extremely". Panelists evaluated the samples independently and recorded their scores for each sensory attribute.

Ethics Approval

Participation was voluntary, and all panelists provided informed consent before sensory evaluation. The evaluation involved tasting commonly consumed bread samples and no personal identifying information was collected.

Statistical Analysis

The sensory evaluation data were analyzed using the Statistical Package for the Social Sciences (IBM SPSS Version 23). Mean scores and standard deviations were computed for each sensory attribute. One-way Analysis of Variance (ANOVA) was used to determine significant differences among the bread samples, while Duncan's Multiple Range Test (DMRT) was used for mean separation at $p < 0.05$.

Results and Discussion

Sensory acceptability of Bread Produced from Wheat Flour Fortified with Moringa Seed Flour

The sensory evaluation of bread produced from wheat flour fortified with moringa seed flour was conducted to determine the influence of fortification on sensory acceptability. Consumer acceptance was assessed using five sensory attributes, namely appearance, taste, texture, aroma, and overall acceptability. The mean sensory scores are presented in Table 1. The ANOVA table showing the F-statistics, degree of freedom and exact p-values are shown in Table 2.

Table 1: Sensory acceptability of bread produced from wheat flour fortified with moringa seed flour

Sample	Appearance	Taste	Texture	Aroma	Overall Acceptability
A (100% Wheat Flour)	8.00 ± 0.943 ^a	7.10 ± 0.994 ^{ab}	7.70 ± 0.675 ^a	7.30 ± 1.160 ^a	7.60 ± 0.699 ^a
B (90% Wheat : 10% Moringa)	7.90 ± 1.370 ^a	7.40 ± 1.350 ^a	6.80 ± 1.687 ^{ab}	7.40 ± 1.506 ^a	7.80 ± 1.398 ^a
C (95% Wheat : 5% Moringa)	6.70 ± 0.675 ^b	6.00 ± 0.667 ^b	6.20 ± 0.632 ^b	5.70 ± 0.823 ^b	6.10 ± 0.876 ^b

Values are Mean ± Standard Deviation. Mean values with different superscripts within the same column differ significantly ($p < 0.05$).

Table 2: The ANOVA table of the Sensory attributes

Sensory attribute	F	df	p-value
Appearance	4.873	2, 27	0.0156
Taste	5.007	2, 27	0.0141
Texture	4.620	2, 27	0.0188
Aroma	6.362	2, 27	0.0054

Sensory attribute	F	df	p-value
Overall acceptability	8.068	2, 27	0.0018

Appearance

Appearance is one of the primary quality attributes influencing consumers' first impression and purchase intention. The mean appearance scores ranged from 6.70 ± 0.68 to 8.00 ± 0.94 . The control bread (100% wheat flour) obtained the highest appearance score (8.00 ± 0.94), closely followed by bread containing 10% moringa seed flour (7.90 ± 1.37). Bread fortified with 5% moringa seed flour recorded the lowest appearance score (6.70 ± 0.68). Statistical analysis indicated that there was no significant difference ($p = 0.0156$) between the control bread and the 10% moringa-fortified bread, whereas both samples differed significantly from the 5% fortified bread. These findings suggest that incorporation of moringa seed flour up to 10% did not adversely affect the visual appeal of the bread and remained acceptable to the panelist. The present findings agree with those of Eke *et al.* (2022), who reported that moderate substitution of wheat flour with defatted moringa seed flour maintained acceptable appearance scores, whereas excessive substitution adversely affected visual quality. However, studies using moringa leaf powder generally reported greater reductions in appearance because of the intense green pigmentation associated with chlorophyll-rich leaves (Trigo *et al.*, 2023).

Taste

Taste is a major determinant of food acceptance because it directly influences consumers' willingness to purchase and consume a product repeatedly. The taste scores varied from 6.00 ± 0.67 to 7.40 ± 1.35 . Bread fortified with 10% moringa seed flour recorded the highest taste score, while the bread containing 5% moringa seed flour received the lowest score. Nevertheless, all samples obtained mean scores above six, indicating that they were liked by the panelists. The improved taste score observed in the 10% fortified bread suggests that moringa seed flour, at an appropriate substitution level, can be incorporated into wheat bread without negatively affecting flavour acceptance. Significant differences ($p < 0.05$) were observed among the bread samples for taste. This finding is consistent with Ogunsina *et al.* (2010) who examined bread containing 0–15% moringa seed flour and reported that bread containing 10% debittered moringa seed flour was most acceptable.

Texture

Texture contributes significantly to consumers' perception of freshness and eating quality. The texture scores ranged between 6.20 ± 0.63 and 7.70 ± 0.68 . The control bread received the highest texture rating, followed by the bread containing 10% moringa seed flour, while the 5% fortified bread recorded the lowest score. Although fortification slightly reduced texture preference, the composite breads remained acceptable, with all samples receiving ratings above the midpoint of the hedonic scale. The results indicate that partial substitution of wheat flour with moringa seed flour had only a moderate influence on the textural characteristics of bread. Reduced texture preference following moringa

incorporation has also been reported by Oyinloye *et al.* (2024), who attributed the changes to dilution of the gluten network and modifications in dough rheology. Nevertheless, moderate substitution levels maintained acceptable textural characteristics (Lü *et al.* 2023).

Aroma

Aroma plays an important role in shaping consumers' perception of bakery products before consumption. The aroma ratings ranged from 5.70 ± 0.82 to 7.40 ± 1.51 . The highest aroma score was recorded for bread fortified with 10% moringa seed flour, while the 5% fortified bread received the lowest rating. The control bread and the 10% fortified bread were not significantly different from each other but were significantly preferred over the 5% fortified bread. The pleasant aroma associated with the 10% fortified bread suggests that moringa seed flour at this substitution level did not produce undesirable odour characteristics that could discourage consumer acceptance. Aroma is an important determinant of consumer preference because volatile compounds generated during baking influence product acceptability. Previous studies have shown that bread fortified with moringa seed generally retains a more acceptable aroma than bread fortified with moringa leaf powder due to the lower concentration of herbaceous volatile compounds (Lü *et al.* 2023).

Overall Acceptability

Overall acceptability represents the combined assessment of all sensory attributes and is regarded as the most reliable indicator of consumer preference. The overall acceptability scores ranged from 6.10 ± 0.88 to 7.80 ± 1.40 . The bread fortified with 10% moringa seed flour achieved the highest overall acceptability score (7.80 ± 1.40), surpassing even the control bread (7.60 ± 0.70), whereas the bread containing 5% moringa seed flour received the lowest rating (6.10 ± 0.88). Importantly, all the bread samples recorded mean scores greater than five, indicating general consumer acceptance. These findings demonstrate that fortification of wheat bread with 10% moringa seed flour was well accepted by consumers and did not compromise overall eating quality.

Similar observations have been reported by Otokpa *et al.* (2019) and Bolarinwa *et al.* (2019), who found that bread fortified with moringa seed flour remained acceptable to consumers while offering additional nutritional benefits.

Overall, the results demonstrate that sensory acceptability of wheat bread was positively influenced by moringa seed fortification. Among the formulations evaluated, bread containing 10% moringa seed flour achieved the highest ratings for taste, aroma, and overall acceptability, while maintaining an appearance comparable to the control. These findings suggest that a 90:10 wheat-to-moringa seed flour blend represents the most suitable formulation for producing consumer-acceptable fortified bread under the conditions of this study.

Limitations of the Study

The findings of this study should be interpreted in consideration of some limitations. First, the sensory evaluation involved only ten panelists, which limits the extent to which the findings can be generalised to a larger population. Second, the panel consisted of staff members and graduate students who were familiar with bread products; therefore, the panel may not fully represent the preferences of the general consumer population. Third, the study was conducted within a single institution and location, and the findings may not reflect possible differences in sensory preferences among consumers from other geographical or demographic groups. In addition, sensory evaluation was conducted during a single assessment session and did not consider possible changes in acceptability during storage. Future studies should involve larger and more diverse consumer populations from different locations and should evaluate sensory acceptability, purchase intention, willingness to pay and product acceptance during storage and under commercial conditions.

Conclusions

This study evaluated the influence of moringa (*Moringa oleifera*) seed flour fortification on the sensory acceptability of bread produced from wheat flour. The findings demonstrated that partial substitution of wheat flour with moringa seed flour had a positive influence on consumer acceptance, indicating that moringa seed flour can be successfully incorporated into bread formulations without compromising desirable sensory qualities. Overall, the sensory evaluation confirmed that all bread samples were acceptable to consumers, as evidenced by mean sensory scores above the midpoint of the nine-point hedonic scale for appearance, taste, texture, aroma, and overall acceptability.

Although the control bread produced from 100% wheat flour received the highest ratings for appearance and texture, bread fortified with 10% moringa seed flour demonstrated comparable consumer preference and achieved the highest scores for taste, aroma, and overall acceptability. These findings suggest that moderate incorporation of moringa seed flour enhances the sensory appeal of bread while maintaining the product characteristics expected by consumers. The results further indicated that the characteristic flavour and aroma imparted by moringa seed flour were well accepted and did not negatively influence consumers' willingness to consume the product.

The study also highlights the importance of sensory evaluation in the development of fortified bakery products. While nutritional enhancement remains a major objective of food fortification, consumer acceptance ultimately determines the commercial success and sustainability of such products. The favourable sensory ratings obtained for moringa-fortified bread demonstrate that sensory acceptability should be considered alongside nutritional improvement when developing functional foods intended for widespread consumption.

Recommendations

Based on the findings of this study, fortification of wheat bread with 10% moringa seed flour is recommended as the acceptable substitution level because it produced bread with excellent consumer acceptability while maintaining desirable appearance, taste, texture, and aroma. The adoption of this formulation could contribute to the development of innovative bakery products that encourage the utilization of moringa seed, promote value addition to indigenous agricultural resources, and expand consumer choices in the functional food market.

Future studies should investigate sensory acceptability using larger and more diverse consumer panels across different demographic groups and geographical locations to enhance the generalizability of the findings. In addition, further research should evaluate consumers' purchase intention, willingness to pay, shelf-life perception, and market acceptance of moringa seed-fortified bread under commercial conditions. Such studies would provide valuable information for the large-scale production and commercialization of moringa-fortified bakery products.

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